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ENDANGERED WATERBIRD AND WETLAND STATUS, KALOKO-HONOKOHAU NATIONAL HISTORICAL PARK, HAWAI'I ISLAND

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ABSTRACT

The endangered waterbirds of Kaloko-Honokohau National Historical Park (KAHO) were studied from February 1992 through 1995, a study begun in conjunction with other avian surveys done during 1992-93 at the three National Park units in west Hawai'i Island (Morin 1996a, 1996b, 1996c). Other simultaneous surveys studied invertebrates, mammals, and vegetation (David Foote pers. comm.; Charles Stone pers. comm.; Pratt and Abbott 1996a, 1996b, 1996c) at those same sites. Endangered Hawaiian Coots or 'Alae ke'oke'o (*Fulica alai*) and endangered Hawaiian Stilts or Ae'o (*Himantopus mexicanus knudseni*) are resident, endemic species and breed at KAHO. Two other resident waterbirds also regularly breed there: the indigenous Black-crowned Night-Heron or 'Auku'u (*Nycticorax nycticorax hoactli*) and the Pied-billed Grebe (*Podilymbus podiceps*). The endangered Hawaiian Moorhen or 'Alae'ula (*Gallinula chloropus sandvicensis*) is believed to have been extirpated on Hawai'i Island in the early 1900s (Banko 1987a). The fourth endangered Hawaiian waterbird species, the Hawaiian Duck or Koloa (*Anas wyvilliana*) has never been confirmed from KAHO's wetlands. Two non-native waterbirds established on Hawai'i Island sometimes visit KAHO, but there are no records they have ever bred there: the Mallard, *Anas platyrhynchos*, and Cattle Egret, *Bubulcus ibis*. In addition to the previously mentioned species, long-term bird sighting records indicate that at least 2 species of migratory geese, 15 species of migratory ducks, 23 species of migratory shorebirds, 11 species of gulls and terns, and 3 other migrant or vagrant species have visited KAHO's wetlands (Morin 1996b). Northern Shovelers (*Anas clypeata*) were the most abundant migrant duck.

Waterbird censuses were made at least weekly in the two KAHO fishponds, 'Aimakapa and Kaloko, for most of the period 1992 through July 1994, and at least twice a month from August 1994 through February 1995. Hawaiian Stilts used both KAHO fishponds, but Hawaiian Coots and migratory ducks did not utilize Kaloko Fishpond, probably due to its deeper water, higher salinity, and inappropriate vegetation. From 1992 through 1994, surveys for waterbird nests were made at both fishponds approximately weekly during the peak breeding season of February through July, and less often otherwise. Endangered Stilt and Coot nests were found only at 'Aimakapa Fishpond, and were concentrated on the northern, southern, and eastern shorelines, coincidentally in the areas most isolated from visitor use. In 1992 no Hawaiian Stilt chicks were found, but after predator control was begun in 1993, Hawaiian Stilts successfully fledged chicks. Hawaiian Coots had poorer recruitment success even with terrestrial predator control, and possible causes include predation on new chicks by large fish in 'Aimakapa Fishpond.

An outbreak of avian botulism caused a large die-off of endangered waterbirds during 1994. Hawaiian Coot mortality at 'Aimakapa Fishpond appeared to be almost 100%, but Hawaiian Stilts sustained lower mortality (Morin 1996d). By December 1995, Hawaiian Coot and Stilt counts were returning to normal at 'Aimakapa Fishpond, but migratory waterfowl counts remained low.

From February 1992 through February 1995 counts of human visitors were made at each fishpond during the bird censuses, and visitor use categorized. Highest visitor counts were on the beach just west of 'Aimakapa Fishpond, and beach-related activities such as sunbathing appeared to be the most frequent visitor use there. The presence of dogs (usually pets) next to

or in the fishponds decreased from 1993 to 1995, probably due to a posted leash law enforced by the Park since approximately 1994.

Predator control at 'Aimakapa Fishpond from February 1993 through December 1994 removed 290 mongooses (*Herpestes auropunctatus*), but also a few cats (*Felis catus*) and a few black rats (*Rattus rattus*). Hawaiian Stilt chick survival appeared to benefit from predator removal.

Experimental wetland weed removal test plots were made and artificial nesting platforms (designed to reduce waterbird nest loss due to frequent flooding and predation) were installed during late 1992 through 1994. Artificial floating nest platforms were readily accepted by both endangered waterbird species, but an adequate anchoring system has yet to be devised. Primarily in Kaloko Fishpond, non-native red mangrove (*Rhizophora mangle*) removal was ongoing during 1992 and 1993. After mudflats became exposed again, Hawaiian Stilts began to reuse those parts of Kaloko Fishpond until the mudflats were reinvaded by the non-native pickleweed, *Batis maritima.* The removal of smaller mangrove infestations also occurred at 'Aimakapa Fishpond and elsewhere in other KAHO wetland and shoreline areas.

KAHO's fishponds and associated wetlands are an important breeding, resting, and feeding site for native endangered waterbirds and are also very important as an overwintering and stopover area for migratory and vagrant waterbirds (Medeiros 1958) and shorebirds. 'Aimakapa and 'Opae'ula (Makalawena) Fishponds taken together have been reported to maintain over 95% of the Stilts and 90% of the Coots for Hawai'i Island (Paton *et al.* 1985). The author has estimated that during 1992-1994 approximately 70-80% of the Hawaiian Coots and 50% of the Hawaiian Stilts for Hawai'i Island were maintained at KAHO's wetlands (Morin 1996d).

Ecosystem-wide hydrology is poorly understood for west Hawai'i Island. Ongoing water-related issues, such as upslope deforestation and non-point source pollution, are impacting brackish water fishponds and other wetlands such as anchialine pools along the Kona coast. In addition, most current and potential waterbird habitat in west Hawai'i Island is not being managed for waterbirds. Frequent, widespread, and close disturbance by humans, vehicles, or pets and feral animals (e.g., dogs, cats) in or next to these wetlands will probably cause the reduction or elimination of endangered waterbird reproduction, and a reduction in numbers and/or types of other waterbirds and shorebirds known to frequent the wetlands, due to increased mortality and the disruption of feeding. Wetland pestiferous alien plant control, and vigorous predator control (e.g., mongooses and cats) will help to stabilize and reverse the wetland ecosystems' ongoing degradation. The future of waterbirds in west Hawai'i Island depends upon proactive wetland management at KAHO and nearby sites regularly visited by these same birds.

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INTRODUCTION AND BACKGROUND

The waterbirds and wetlands on Hawai'i Island are poorly studied, with both wetlands and waterbirds occurring in low numbers relative to the other geologically older Hawaiian Islands. Wetlands along the western coast of Hawai'i Island are primarily clusters of brackish water anchialine pools surrounded by lava flows, or ancient man-modified wetlands, ponds, and anchialine pools and embayments identifiable as Hawaiian fishponds, all of which experience tidal fluctuations. For waterbirds, the most important of the fishponds on the Kona coast are 'Aimakapa, Kaloko, and 'Opae'ula (Makalawena) Fishponds, but especially 'Aimakapa (Elliott and Hall 1977; Shallenberger 1977). 'Aimakapa and Kaloko lie within the boundaries of the federal Kaloko-Honokohau National Historical Park (KAHO) and 'Opae'ula is the private property of Kamehameha Schools/Bishop Estate. However, there are many other unprotected anchialine pools and fishponds scattered along the Kona coast that provide important peripheral waterbird habitat (Anon. 1989, Morin 1994a). Relatively recent man-made features, such as the algal ponds of Cyanatech at the Natural Energy Laboratory, Keahole Point (since at least the early 1990s), and the sewage treatment plant (since 1994) have also become important waterbird foraging sites.

Relatively stable population counts on Hawai'i Island suggest that Hawaiian Stilts do not commonly fly between Hawai'i Island and the other main islands, although until about 1995 specific information was lacking (Engilis and Pratt 1993, Paton *et al.* 1985, Reed *et al.* 1994, Reed *et al.* 1998). Although most documented Hawaiian Stilt movements were on the same island where the stilt was banded, stilt were shown to be capable of extensive inter-island movement, and a few moved between islands several times (Reed *et al.* 1998). Inter-island movement has been documented for Hawaiian Coots, although not specifically between Hawai'i Island and the other main islands (Banko 1987, Engilis and Pratt 1993). Relatively stable Coot population counts in west Hawai'i Island suggest that inter-island and even intra-island movements are uncommon.

The results presented in this technical report are from baseline avian studies done at KAHO in Kona, Hawai'i Island, from 1992 through 1995. This paper focuses primarily on waterbird breeding and wetland ecosystem status at KAHO, but acknowledges the profound interrelationship of the wetlands in west Hawai'i relative to waterbird habitat and overall waterbird population maintenance. The major species of interest were the resident, federally-listed endangered Hawaiian Stilts and the endangered Hawaiian Coots. However, a wide variety of migrants pass through or overwinter at 'Aimakapa Fishpond in KAHO (Paton and Scott 1985). A few Pied-billed Grebes, a family of indigenous Black-crowned Night-Herons, and a single feral female Mallard were resident. Introduced Cattle Egrets sometimes visit in small numbers; however, their rookery is not in KAHO and is not known to occur nearby.

Although endangered Koloa maoli or Hawaiian Ducks are reported to occur on Hawai'i Island (Engilis and Reid in prep.), the author has never seen them at either fishpond in KAHO. No verified records of Koloa at KAHO are known to exist, although Koloa were reported at 'Opae'ula in the early 1970s and are regularly seen in Kohala Mountain reservoirs (Paton and Scott 1985).

The fourth endangered native waterbird, the Hawaiian Moorhen or 'Alae 'ula, which is still extant on the other main islands, has been extinct on Hawai'i Island since "probably not long after the turn of the century" (Banko 1987a). Since then, a single unconfirmed Moorhen sighting was made in 1982 at 'Opae'ula Fishpond (Pyle 1983).

Very few waterbirds currently use Kaloko Fishpond for foraging and loafing, and breeding was not documented there during the study period. After the successful removal of an invasion of non-native red mangrove from Kaloko Fishpond in 1992, Hawaiian Stilts have occasionally foraged there in small numbers, even though extensive past dredging at Kalôko has made it "nearly worthless" as a waterbird habitat in comparison to 'Aimakapa (Shallenberger 1977). Hawaiian Coots and migratory waterfowl do not utilize Kaloko in its current state, probably because of its high salinity, inappropriate vegetation, and water depth, although Shallenberger (1977) reported that both Coots and Stilts had been seen there. From 1961 to 1981, an average of 0.9 Stilts (a total of 25 birds) were seen at Kaloko Fishpond during 29 counts (Banko 1988). Banko (1987b) reported that from 1959 to 1981 a total of 9 Coots were seen at Kaloko Fishpond during 17 different counts but all sightings were prior to about 1971, presumably before Kaloko was dredged and the rapid invasion of non-native mangrove drastically altered the habitat. Aside from the recent Stilt use (that resumed after mangrove was removed and some mudflats were cleared of alien pickleweed), Kaloko Fishpond currently sustains only a few migratory shorebirds and Black-crowned Night-Herons.

Mongooses are known to be very numerous in the Hawaiian lowlands, including around both fishponds in KAHO. Feral cats and dogs are also frequent visitors. Studies elsewhere have verified that these mammals have a very significant impact on the maintenance of endangered waterbirds at any given site (Coleman 1981). In fact, at Chang's (1990) study site on O'ahu, he concluded that predation was the biggest cause of nest loss for all four species of endangered Hawaiian waterbirds.

In January 1994 an outbreak of avian botulism type C (*Clostridium botulinum*) began killing waterbirds at 'Aimakapa Fishpond and elsewhere along the coast (Morin 1994b). The endangered Hawaiian Coots were the hardest hit, along with migratory Northern Shovelers (*Anas clypeata*); there was also some mortality among the endangered Hawaiian Stilts. The Coot population went from a high of over 100 individuals to a count of one in October 1994. The die-off obviously had serious ramification for the breeding study, as well as for the long-term maintenance and management of waterbirds in west Hawai'i.

STUDY SITE

Kaloko-Honokohau National Historical Park lies on the Kona coast at the base of the volcano Hualalai. It is bordered on the south by Honokohau Harbor, a major Highway on the east, proposed resort development on the north, and the Pacific Ocean on the west. An industrial park lies immediately upslope of the Highway to the east. In addition to many Hawaiian cultural values (Kelly 1971), KAHO has outstanding wetlands, which include 'Aimakapa Fishpond, Kaloko Fishpond, 'Ai'opio Fishtrap, rocky tidal areas, and numerous anchialine pools (Macioleck and Brock 1974, Chai 1991). KAHO contains some of the most productive endangered waterbird wetlands on Hawai'i Island (Shallenberger 1977, Engilis and Reid in press).

Kaloko Fishpond is about 4.5 ha of water, 'Aimakapa Fishpond approximately 6 ha of open water and another 6 ha of marshland that was once fishpond (Fig. 2), and 'Aio'pio Fishtrap about 0.7 ha (Kikuchi and Belshe 1971).

Both 'Aimakapa and Kaloko Fishponds are brackish due to considerable subsurface fresh water from upslope, where coastal springs mix with ocean water (Parrish *et al.* 1990); however, there are considerable variations in salinity due to tidal stage, location, and sample depth (Kikucki and Belshe 1971). Both fishponds experience tidal fluctuations, although at 'Aimakapa there is a lag in tidal effects.

Water samples taken in 1994 at 'Aimakapa Fishpond by USGS Water Resources Division (William Meyer, USGS, pers. comm.) indicated that the fishpond had a salinity of about 13 ppt, only slightly saltier than the groundwater (10 ppt) and considerably less salty than seawater (35 ppt). Kaloko Fishpond is currently much more saline than 'Aimakapa, with salinities ranging from 18-34 ppt (William Meyers, pers. comm.). In 1971, Kikuchi and Belshe described the central waters of 'Aimakapa Fishpond as having a temperature of 27.8 ^{o}C and a salinity of 7.9 ppt. They described Kaloko Fishpond as a layered body of water, with surface temperatures of 20-24 ^{o}C and salinities that ranged from 18-24 ppt in the deeper areas and temperatures of 18-20 ^{o}C and salinities of 4-8 ppt near the springs in the shallow back areas. Macioleck and Brock (1974) reported the salinity of 'Aimakapa as 7-8 ppt. Chai (1991) stated that his 1988 fieldwork indicated Kaloko Fishpond had greater freshwater influx in 1971 than during 1988. However, since the 1960s, the seawall at Kaloko Fishpond has been damaged repeatedly by storms, and salt water flows freely into the fishpond, especially during high tides.

The vegetation in the wetland areas of KAHO was described by Canfield (1990) and Pratt and Abbott (1996b). A major infestation of nonnative red mangrove was removed from Kaloko Fishpond in the early 1990s, and the clearing allowed an overwhelming invasion by a different nonnative, *Batis maritima* (pickleweed or 'akulikuli kai).

The wetlands immediately surrounding 'Aimakapa Fishpond are still dominated by native vegetation, including water hyssop (*Bacopa monnieri*), makaloa sedge (*Cyperus laevigatus*), native sea purslane or 'akulikuli (*Sesuvium portulacastrum*), and kaluha sedge (*Bolboschoenus maritimus* subsp. *paludosus*). Hau (*Hibiscus tiliaceus*) and milo (*Thespesia populnea*) trees, both possible Polynesian introductions, are the major woody plants in the 'Aimakapa wetlands.

MATERIALS AND METHODS

WATERBIRD POPULATION CENSUSES

Waterbird censuses were taken at least weekly at 'Aimakapa and Kaloko Fishponds from February 1992 through July 1993, and from January 1994 through July 1994, and at least twice a month from August 1994 through February 1995, and intermittently thereafter. Counts of all waterbirds and shorebirds were made with binoculars from the western shore of 'Aimakapa Fishpond or the southern shore of Kaloko Fishpond. Censuses were also made along the shoreline for the sections of 'Ai'opio Bay visible from the spot where the restroom trail emerges from the coastal strand vegetation and continuing along the shoreline to the beach berm immediately west of 'Aimakapa Fishpond: these counts will be referred to as "Shoreline". Parts of the 'Ai'opio Fishtrap shoreline were inhabited by permittees during 1992 through 1995 and closer scrutiny was not advisable. Censuses at both fishponds were usually made within one hour of each other. The author made all censuses. Copies of all bird censuses made by the author during these studies were given to Bob Pyle at Bishop Museum, Honolulu, and to The Nature Conservancy, Honolulu, as well as to Cliff Smith at CPSU, Dept. of Botany, Honolulu, and the Resource Manager of KAHO, in Kona.

WATERBIRD REPRODUCTION

Waterbird reproduction was studied at KAHO during the time period from February through December 1992, January through July 1993, and January through December 1994. No adult waterbirds were banded as part of this study, although a few Hawaiian Stilt chicks were banded in 1993 and 1994 by a visiting researcher, Dr. J. Michael Reed (see Reed *et al.* 1998).

Waterbird nesting territories were recorded during population censuses made at least weekly at both 'Aimakapa and Kaloko Fishponds, and nest surveys were made from an inflatable kayak approximately weekly at 'Aimakapa. The behavior of adult pairs, including displays and habitat utilization, were used to help locate nest sites. All nests or nest-like formations that were located were recorded but only nests where eggs and/or chicks were seen were included in the data set. The highest number of eggs seen in a nest was recorded as the clutch size, and the number of fledglings was the number seen a month or more after hatching. Great care was taken when counting Coot broods, because the parents will sometimes split the brood (Byrd *et al.* 1985, Morin pers. obs.). Nests in 'Aimakapa Fishpond were mapped in reference to "Ponds" 1 through 4 as delineated by rockwalls.

Once a nest had eggs, its nest substrate was assigned to one of six categories: FLOATING, a free-floating nest constructed by either a Coot or a Grebe; FLOATING VEG., a nest constructed on top of a mat of floating vegetation, generally the nonnative grass, *Paspalum sp.*; ISLET, a small, natural island surrounded by water; PLATFORM, a square or rectangular floating manmade wooden platform; ROCKWALL, a hand-pieced lava rock wall, part of the fishpond structure and partially covered with some vegetation like grass or the native 'ākulikuli *(Sesuvium portulacastrum)*; and SHORELINE, the fishpond shoreline, much of which now looks like "fast" land but in the past was floating vegetation that has collected and stabilized silt. The nest substrate was considered to be "missing data" when broods were found after they had left the nest, and therefore the substrate was never identified. In most of these instances, the approximate nest area was known due to past behavior by paired adult birds presumed to be their parents.

Nest outcomes were assigned based on best information available from the field surveys. The outcomes were assigned into one of seven categories: ABANDONED, nest abandoned; DISAPPEARED, eggs or chicks were seen but disappeared abruptly; FLEDGED, at least one chick fledged from the nest; HIGH WATER, nest with eggs destroyed by high water from storm surge or high tide; NEST SANK, the floating nest sank; PREDATION, predators apparently destroyed the eggs or chicks; and UNCERTAIN, unable to assign an outcome category to the nest.

ARTIFICIAL FLOATING NEST PLATFORMS

In late 1992 and early 1993, 10 artificial floating platforms were placed in each of the fishponds. These floating platforms were an attempt to mitigate the nest destruction and egg mortality caused by "high" high tides and storm surge, and also to reduce predation by terrestrial predators. Five of the ten in each pond were 2' x 2' hardware "cloth" covered with dried grass and attached to three pool floats (hereafter referred to as "wire baskets") and the other five in each pond were constructed out of kiln-dried untreated wood (hereafter referred to as "wooden platforms"). The wooden platforms were either 0.6m x 0.9m or 0.6m x 0.6m, constructed of 2" x 4" lumber, with 1/2" rim of untreated wood lathing. Holes bigger than an inch-diameter dowel were drilled in two corners of the platform, at diagonal corners, and one or two dowels or closet rods were inserted in the holes and used to anchor the floating platforms in the mud on the bottom of the fishpond. The platforms were not adjacent to land, but were free floating, anchored by the dowels. The wooden and wire platforms were placed in "paired" positions throughout the two ponds in order to determine nest site preference. In 1994, seven of the "wire baskets" and ten of the wooden platforms were positioned in 'Aimakapa and four wooden platforms were also placed in Kaloko Fishpond.

PREDATOR CONTROL

During the 1992 breeding season, no manipulations were made to the wetland habitats and no predator trapping was done immediately around 'Aimakapa Fishpond. Two live-trapping small mammal grids, one near 'Aimakapa Fishpond and one near Kaloko Fishpond, were operated briefly during 1992 and again in 1993 in order to estimate mongoose, cat, and rat densities: this data will be presented and published elsewhere (C. Stone pers. comm.). In 1993 and 1994, a trap line was laid around 'Aimakapa Fishpond; mongooses, cats, and a few rats were trapped and removed. Trapping began with 30 traps on 18 February 1993, was increased to 32 traps on 23 February, increased again to 34 traps on 9 March, and finally was increased to 42 traps on 16 June 1993, and was left at this number. Traps were provided with water bottles, and were generally checked every other day. Live cats with collars were taken to the nearby animal shelter. Otherwise, animals were humanely euthanized with the gas Halothane and their bodies were disposed of away from the fishpond outside the Park.

WETLAND VEGETATION MANAGEMENT

As part of a separate project at KAHO during 1992 and 1993, non-native mangrove removal was on-going in Kaloko Fishpond and in selected areas adjacent to 'Aimakapa Fishpond, on both north and south ends of the 'Aimakapa wetland. A few mangroves established in 'Aimakapa Fishpond itself were also removed. Shoreline and anchialine pools were periodically searched for mangroves, which were then removed. Large mangrove was removed with chain-saws, cutting below the level of the uppermost roots at the waterline. Small mangroves were either pulled by hand or killed by scorching with propane torches.

In December 1992 and January 1993, four 4m x 4m paired vegetation plots were marked around 'Aimakapa Fishpond, and four 4m x 4m paired plots at Kaloko Fishpond. One block of each pair was cleared of vegetation and one block was left vegetated as a "control" plot. Vegetation removal at 'Aimakapa involved primarily alien *Paspalum* knotgrass removal, whereas at Kaloko Fishpond *Batis maritima* was the primary alien plant removed. In addition, several small islets were cleared of vegetation in both 'Aimakapa and Kaloko Fishponds, as well as a small mudflat next to the main dividing rock wall in Kaloko Fishpond. Vegetation control was accomplished via manual removal and/or covering plants with black plastic sheeting until they died: no herbicides were used. At Kaloko Fishpond, technicians were instructed to leave any native plants within the plots as they "cleared" them, so that these remnant native plants could revegetate the area before *Batis* reestablished itself. Native plants which were left in situ at the Kaloko plots (whenever possible) included: *Lycium sandwicense* ('ohelo kai), *Sesuvium portulacastrum* ('akulikuli), *Bacopa monnieri* (water hyssop), and *Cyperus laevigatus* (makaloa). Plots and other cleared sites (e.g., islets) were monitored during waterbird censuses and nest surveys.

VISITOR NUMBERS AND ACTIVITIES NEAR FISHPONDS

From February 1992 through February 1995, the numbers of visitors and dogs adjacent to or in the two fishponds, and the type of visitor activity, was recorded prior to waterbird censuses. These visitor counts were "snapshots" of the visitor use and did not attempt to record visitor turnover. Dogs present on the beach that were not initially seen during the survey were recorded once they were detected. The inclusive area for 'Aimakapa Fishpond was the pond itself, the littoral zone (out to about 50 m), and the entire sandy beach, beginning where the trail from the harbor parking lot emerged from the coastal strand of trees and emptied onto the shoreline, and ending at the rocky shoreline prominence north of 'Aimakapa beach. Any visitors

east of the berm in the 'Aimakapa Fishpond wetlands were also recorded, including official Park personnel. These areas could be seen quickly and easily while walking to the fishpond or from the west edges of the fishpond.

The inclusive area for Kaloko Fishpond was the pond itself, the parking lot, the picnic/beach area and rocky tidal zone, the rock wall that separates Kaloko Fishpond from the ocean, and the perimeter of Kaloko Fishpond that could be seen from its southern and southwestern edges.

Although not all counts were paired, "paired" counts are defined as visitor counts that were made at both fishponds on the same day and usually within an hour of each other.

Persons were categorized either as official Park personnel (including the author) or as a regular visitor. Activities were assigned only if seen in the short time period of the actual survey: "WATER PLAY" (persons in the ocean swimming, snorkeling, scuba diving, etc.), "CONSUMPTIVE USE" (such as fishing, limu or other ocean collecting, based on presence of fishing gear, nets, and buckets), "BEACH/BERM" (persons loafing, sunbathing, or bird-watching on the beach west of Aimakapa Fishpond, or on the beach or hanging out in the parking lot at Kaloko Fishpond). The latter category probably included multiple users, many of whom also swam, snorkeled, fished, or collected marine resources during their visit but were not observed doing those activities. A separate category, "TOO CLOSE", indicated (for 'Aimakapa Fishpond) persons either on the eastern side of the sandy berm or in 'Aimakapa Fishpond itself or its immediately adjacent wetlands. For Kaloko Fishpond, "TOO CLOSE" indicated someone was in, or right next to, the southeastern "finger" projection of the fishpond, a wetland site used periodically by endangered stilts after the mangrove was removed. Each person was assigned to only one use category. All visitor counts should be viewed as minimum estimates, since visitors were known to use sites screened from view by coastal shrubs and trees.

BOTULISM

During the 1994 botulism outbreak at KAHO, most dead birds at 'Aimakapa Fishpond were retrieved from the shoreline or by boat, primarily by technicians checking a predator trap line several times a week. Some carcasses were retrieved during the waterbird censuses and nest surveys. Dead birds were retrieved by net or by hand using protective plastic gloves. Carcasses were bagged in plastic: most fresh carcasses were packed on ice and flown to Thierry Work, the federal D.V.M., in Honolulu for verification of botulism toxin. Decayed carcasses were bagged and taken directly to the carcass disposal freezer at the Humane Society in Kona, or frozen at KAHO and later taken to the Humane Society. Frozen carcasses were disposed of periodically by the Humane Society at the landfill in Pu'u Anahulu according to their dead animal disposal guidelines.

RESULTS

WATERBIRD POPULATION CENSUSES

Waterbird and shorebird species from complete counts done at 'Aimakapa (AP) and Kaloko (KP) Fishponds, and the shoreline and rocky ledge just north of 'Ai'opio Fishtrap and south of 'Aimakapa Beach (SA) are listed in Table 1, in decreasing order of their abundance at 'Aimakapa. A complete count was defined as a census where every species of water and shorebird present was identified and counted, as opposed to a count where only selected species (e.g., endangered Hawaiian Coots and Hawaiian Stilts) were counted.

Migratory Ducks

Especially during the months of November through April, migratory ducks were often the most numerous bird species' seen at 'Aimakapa Fishpond. During this study, the earliest reported date-of-arrival for a migrant duck (three American Wigeons) was 25 September 1992 (see Fig. 3), and the latest date-of-departure for migrant ducks was 27 May 1994 (a Northern Shoveler). Other than one duck seen on one occasion (Table 1), ducks were not seen using Kaloko Fishpond, probably due primarily to its higher salinity.

Northern Shovelers were the most frequent species counted at 'Aimakapa Fishpond, but other less common species included Northern Pintails (*Anas acuta*), American Wigeon (*Anas* americana), Redheads (Aythya americana), Canvasbacks (Aythya *valisineria*), Ring-necked Ducks (*Aythya collaris*), Greater Scaup (*Aythya marila*), and Lesser Scaup (*Aythya affinis*). Although the early months of the 1991-1992 migratory season were missed (Fig. 3), from 18 February through 12 May 1992, the mean migratory duck count was 56.7 ducks (SD = 33.2, n = 20 counts, range 1 to 97). The entire 1992-1993 migratory season was observed, with an average migratory duck count of 25.0 (SD = 21.0, n = 38, range 3 to 66). Aside from a single count taken in November 1993, the earliest months of the 1993-1994 migratory season were missed, but the rest of that season's counts were taken from 5 January 1994 through 27 May 1994: the average duck count at 'Aimakapa Fishpond was 47.0 (SD = 35.1, n = 26, range 1 to 145 ducks). During the 1994-1995 migratory duck season, few counts were taken and all counts were low. Several bird censuses during the typical migratory duck peak recorded that no migrant ducks were present. For non-zero counts taken during 1994-1995, the average migratory duck count was 9.2 (SD = 9.0, n = 9, range 1 to 25 ducks). A single Redhead (presumable the same one seen repeatedly, since Redheads are considered rare stragglers to Hawaii Island: see Paton and Scott 1985), a single Pintail, and between 9 and 24 Shovelers were the only migrant ducks counted. Two usual migrant species, Lesser and/or Greater Scaup, were not seen; Lesser Scaup are usually seen every year (Paton and Scott 1985, Morin pers. obs.). For all the duck counts mentioned previously, only non-zero counts were used to calculate the means and standard deviations (SD).

Hawaiian Coots

For all censuses taken at 'Aimakapa Fishpond from August 1990 through December 1995 (Fig. 4), the mean number of birds per count for endemic Hawaiian Coots was 45.0 $\pm$ 23.9 SD birds (n = 168 censuses, range = 0 to 103). For the baseline censuses from February 1992 through July 1993, the coots averaged 56.5 $\pm$ 13.3 SD birds per census (n = 109, range = 29 to 80). During 139 censuses made at Kaloko Fishpond, no Hawaiian Coots were ever seen there.

Hawaiian Stilts

For all censuses made at 'Aimakapa Fishpond from 1990 through December 1995 (Fig. 5), the mean number of Hawaiian Stilts per count was 12.9 $\pm$ 5.0 SD birds (n = 179 censuses, range = 0 to 29). For the baseline censuses from February 1992 through July 1993, the mean was the same: 12.9 $\pm$ 4.7 S.D. Stilts, n = 117, range = 0 to 29).

Hawaiian Stilt counts at Kaloko Fishpond increased from 0.3 $\pm$ 0.8 SD Stilts per census (n = 82, range = 0 to 3) during baseline counts (February 1992 through July 1993) to 2.1 $\pm$ 3.8 SD Stilts per census (n = 49, range = 0 to 18) during 1994.

Other Migrants and Resident Waterbirds

"Shoreline" counts (see Table 1) made during the walk to 'Aimakapa Fishpond usually were comprised of common shorebirds such as Wandering Tattlers or 'Ulili (*Heteroscelus incanus*), Ruddy Turnstones or 'Akekeke (*Arenaria interpres*), Pacific Golden-Plover or Kolea (*Pluvialis fulva*), and Sanderlings or Hunakai (*Calidris alba*). Hawaiian Stilts were often sighted feeding in the rocky tidal flats just north of 'Ai'opio Fishtrap (Table 1).

The common shorebirds listed in the preceding paragraph were also found frequently along the shorelines of 'Aimakapa and Kaloko Fishponds. A few Pied-billed Grebes were always present and usually seen at 'Aimakapa Fishpond. In addition, Black-crowned Night-Herons and introduced Cattle Egrets were periodically seen at 'Aimakapa Fishpond. A few resident Black-crowned Night-Herons were sometimes seen at Kaloko Fishpond, although the lack of grassy foraging habitat at Kaloko Fishpond apparently discouraged Cattle Egrets from using it.

WATERBIRD REPRODUCTION

Breeding Season

During the three years of this study at 'Aimakapa Fishpond, Hawaiian Stilt nests with eggs were found from February through July with a peak from March through June (Table 2).

Hawaiian Coot nests with eggs were found in all months except November and January, with a peak from April through July (Table 2). In 1994 during the botulism outbreak at 'Aimakapa, Coot breeding did not occur at the pond during the months of January through April.

Black-crowned Night-Herons bred within KAHO in small numbers: perhaps just a single family group. Their breeding season is thought to be approximately May to June. They nest in inaccessible areas with dense shrubs and low trees near KAHO's wetlands.

Besides the occasional Black-crowned Night-Heron, the only other waterbirds currently breeding at 'Aimakapa are Pied-billed Grebes. Grebe nests with eggs were found during all months except January, November, and September, with a slight peak from May through July.

Blue-winged Teal (*Anas discors*) no longer nest at 'Aimakapa Fishpond, although they were documented to do so in 1982 and 1983 (Paton *et al.* 1984). In fact, this migrant duck species was not seen by the author at 'Aimakapa during the years of this study.

Nest Site Placement

No waterbird nests of any type were detected in Kaloko Fishpond during this study.

At 'Aimakapa Fishpond, the breeding endemic species appeared to display a high degree of predictability in their habitat use. The year-by-year maps for Hawaiian Coot nest sites are shown in Figs. 6, 8, and 11, and for Hawaiian Stilts in Figs. 10 (1993) and 13 (1994). No Stilt nests with eggs were found in 1992 and chicks were not seen. However, during 1992 probable nest "scrapes" were seen and adult Stilts exhibited the well-known "injury" distraction displays aimed at leading potential predators away from nests.

Grebe nest placements from 1992 through 1994 are indicated on Figs. 7, 9, and 12. No other waterbird nests were detected at 'Aimakapa during these three breeding seasons, except

1992 when a pair of Black-crowned Night-Herons nested in alien mangrove trees just prior to the trees' removal in the wetland area immediately north of the fishpond. However, juvenile Black-crowned Night-Herons were seen at 'Aimakapa Fishpond each year, indicating that they had nested within the park or nearby.

Overall nest sites for the two endangered species in 'Aimakapa Fishpond from 1992 through 1994 are shown combined on Fig. 14. Nests were clearly concentrated on the eastern half of the fishpond.

The sections of 'Aimakapa Fishpond most frequently used by all the three breeding species for nesting were "Pond" 1 and "Pond" 2 (Fig. 15, Table 3.). Preference varied by species: Hawaiian Coots had the most nests in "Pond" 1 and "Pond" 3, and Hawaiian Stilts had the most nests on the North Shore and in "Pond" 1. Pied-billed Grebes used "Pond" 2 most often.

Every Stilt nest site was at or very near a mudflat; mudflats are essential for chick foraging immediately after hatching, since adult Stilts do not feed their precocial chicks. The mudflats currently available for nest sites/chick feeding are shown in Figure 15.

There were 52 different known sites used for nesting, 22 of them more than once, and three of those 22 sites were used by two different species (not simultaneously). The sites used most frequently were sites E and H (see Nest Substrates section): each was used a total of six different times.

Nest Substrates

The substrates used as nest sites by the three species (Coot, Stilt, and Grebe) are summarized in Table 4. Hawaiian Coots most frequently built nests on islets, but also liked floating vegetation. Hawaiian Stilts most frequently built nests on the floating wooden platforms, but they built nests on the northern shoreline almost as frequently. The wire basket type of floating platform was never used by any species for nesting, although they were used for resting. Pied-billed Grebes only built free-floating nests or built nests on top of floating vegetation.

The two most frequently used sites (each used six times) were an islet and a naturally floating nest. Site E was the small, isolated natural islet outside of "Pond" 3; Coots used it repeatedly. Site H was a floating but "anchored" natural nest in "Pond" 1, constructed and used repeatedly by Grebes (see Fig. 15).

Clutch Size

No stilt nests with eggs were located at 'Aimakapa in 1992. The mean number of eggs per Hawaiian Stilt clutch was 3.4 for 1993 and 1994 combined (Table 5a), with slightly more eggs per clutch in 1993 than 1994, although the difference was not significant at the 0.05 level (using the nonparametric version of a t-test: the Mann-Whitney U-test, with the result of $P = 0.61$). The modal clutch size was 4 eggs, which comprised 68% of the Stilt clutches (Fig. 16).

Hawaiian Coot clutches averaged 5.0 eggs (Table 6a.) and was not significantly different among years at the 0.05 level (using the nonparametric Kruskal-Wallis test, with a resultant $P = 0.99$). The modal clutch size of 6 eggs comprised 30% of the coot nests (Figure 16) and is more representative of the usual coot clutch size.

The Pied-billed Grebe nests had an average clutch size of 2.4 (Table 7a.). The modal clutch size was 2 eggs with a range of 1 to 5 eggs per clutch.

Fledging Success

The overall frequency of fledglings per nest is shown for Hawaiian Stilts and Hawaiian Coots on Figure 17 and the mean fledglings per nest per year on Tables 5b and 6b.

In 1992 no fledgling Stilts were known to be raised at 'Aimakapa. In 1993 an average of 0.9 fledglings were produced per Stilt nest, and in 1994 the average increased to 1.6 fledglings per nest (Table 5b.), although no statistical difference was detected (Mann-Whitney U-test, P = 0.21).

The numbers of fledgling Coots per nest were basically the same (0.8 fledglings per nest) in 1992 and 1993. In 1994, the fledgling rate dropped to 0.5 fledgling coots per nest (Table 6b.), but again, no statistical difference was detected (Kruskal-Wallis test, P = 0.71).

No fledgling Grebes were ever documented from the nests followed during this study (Table 7b.).

Nest Outcomes

Table 8 summarizes the outcomes for nests with eggs by species for all three years. Year-by-year outcomes varied greatly (Tables 9, 10, and 11).

For Hawaiian Coots, destruction of nests by high water was the overall leading nest fate (Tables 8 and 9). Hawaiian Stilt nests (after 1992) most often resulted in the fledging of one or more chicks (Tables 8 and 10). Pied-billed Grebe nests with eggs were usually either abandoned or destroyed by high water (Tables 8 and 11). The single Coot nest known to have fledged chicks off a wooden platform had a higher fledging success than a Coot nest on any other substrate (Table 12). Even though islets were the preferred nest substrate for Coots (Table 4), the platform and the shoreline produced better fledging results.

Although Hawaiian Stilts most frequently chose wooden platforms and the shoreline for nest sites (Table 4), they had the best fledging success from islets and rockwalls (Table 12).

ARTIFICIAL FLOATING NEST PLATFORMS

Artificial floating platforms were not used for nesting by any waterbird at Kaloko Fishpond during this study, although Hawaiian Stilts were frequently seen resting on them. However, no waterbird nests were found anywhere in Kaloko Fishpond.

Artificial floating nest platforms were not available for nesting during most of 1992, since they were built and installed in late 1992, after the Stilt breeding season. In 1993, Hawaiian Coots made nests on two wooden floating platforms in 'Aimakapa (Fig. 8), and one nest on a wooden platform in 1994 (Fig. 11). However, two of the three Coot nests on floating platforms had unknown numbers of eggs in the clutches and had uncertain outcomes. The single Coot nest with a known outcome had the best fledging of any Coot nest in the study: 5 fledglings (see Table 12).

Once they were installed, floating wooden platforms were the most popular nest substrate used by Hawaiian Stilts (Table 4). In 1993, 5 Stilt nests were built on three different wooden platforms (Fig. 10). Two of the late nests are believed to have been renests by the same pairs, which was suggested by tolerant behavior of the adults when young-of-year visited the second nest at each site. However, none of the adult Stilt were banded and it is possible, although unlikely, that different pairs built the second nests. In 1994, during the botulism outbreak, three nests were built by three different pairs on wooden platforms (Fig. 13). Although Stilts most frequently chose floating platforms as nest substrates in 1993 and 1994, fledging from floating platforms only averaged 0.8 fledglings per nest, or about one offspring per nest attempt (Table 12). But, two of the eight Stilt nests built on floating platforms fledged 3 fledglings each, and at least another two of the eight nests were lost to high water damage, suggesting that more stable anchoring of the wooden platforms could have significantly increased Stilt fledging success from the floating platforms.

The "wire basket" type of floating platform was never used for nest attempts by any species, although waterbirds used them for resting.

PREDATOR CONTROL

Seven cats, 290 mongooses, and 9 rats were either taken to the Humane Society or euthanized after being removed by live-trapping in the wetland area around 'Aimakapa Fishpond from February 1993 through December 1994 (Figure 18). After the first four months of trapping, the number of trapped mongoose fell to a relatively lower maintenance level. Rats were not specifically targeted for removal, but were trapped accidentally. In addition to mammals targeted for by the trapping, one feral pig and one feral dog were removed.

Although a direct cause-and-effect relationship cannot be proven, no Hawaiian Coot nests were found on the shoreline of 'Aimakapa Fishpond in 1992 prior to trapping (Fig. 6) and no Stilt nests or fledglings were found at 'Aimakapa Fishpond in 1992 prior to trapping. However, the apparent increase in waterbird breeding and breeding success after predator control began is unlikely to be merely coincidental.

WETLAND VEGETATION MANAGEMENT

Due to lack of personnel, cleared islets and the cleared and control plots at Kaloko and 'Aimakapa Fishponds could not be adequately monitored. Observations were made periodically, primarily during other activities such as waterbird counts and nest surveys, and maintenance of floating nest platforms. After removal of non-native mangrove in Kaloko Fishpond, mangrove roots rotted rather quickly and nonnative pickleweed quickly invaded the shoreline, mudflats, and anchialine pools. Pickleweed removed from control plots at Kaloko Fishpond quickly reestablished itself, primarily because the roots were difficult to completely remove manually and short stalks and leaves which floated in from adjacent sites during higher tides (pickleweed is buoyant) can apparently take root. Pickleweed was difficult, although not impossible, to kill by covering with heavy black plastic sheeting.

Cleared plots in 'Aimakapa Fishpond also revegetated quickly, although the *Paspalum* grass did not reinvade as quickly as pickleweed did in Kaloko Fishpond.

Anecdotal observations indicate that Hawaiian Stilts and shorebirds were quick to utilize the cleared areas as foraging sites at both fishponds, and several cleared islets at 'Aimakapa Fishpond were also used as nest sites for the first time (Morin pers. obs.).

VISITOR NUMBERS AND ACTIVITIES NEAR FISHPONDS

Two hundred and fifty-five visitor counts were made at various times of the day (Fig. 19), with midday over-represented, and early morning and late afternoon under-represented. One hundred and forty-six visitor counts were made at 'Aimakapa Fishpond and 109 were made at Kaloko Fishpond. At each pond, 91 (182 counts) were "paired" counts, where counts were made at both fishponds on the same day and usually within an hour of each other. These paired counts allow a slightly better comparison of visitor use between the ponds, because they control somewhat for day-of-week, time-of-day, and weather.

Dogs

Dogs, usually unleashed and brought by their owners, were commonly seen at 'Aimakapa Fishpond in 1992 and 1993 but were seldom seen at Kaloko Fishpond (Table 13). Dogs were usually seen along the western shoreline of Aimakapa. Dogs were seen less often in 1994. None were seen during the few 1995 counts.

Humans

An average of 21 persons (including the author) were counted during any given visit to Aimakapa Fishpond during 1992 through early 1995 (Table 14). Kaloko Fishpond had an average of 7 visitors (including the author) for any given visit, although during that time period, the number of official Park personnel decreased while the visitor use appeared to increase (Table 15). Although counts of official Park personnel are quite accurate, visitor counts represent minimum counts, since visitors sometimes picked concealed resting sites.

Most common activities at the beach near 'Aimakapa Fishpond during the times surveyed were sunbathing (especially clothing-optional) and swimming. Almost all human activity at 'Aimakapa Fishpond was concentrated on the top of the sand berm and on the eastern side of the berm facing the ocean. At Kaloko Fishpond's small walled beach, picnicking and resting were popular, and most of the use occurred on the beach, rocky tidal area, or in the parking lot. Consumptive uses like fishing and collecting of marine resources were relatively uncommon at both sites, but were more common at Kaloko Fishpond (Table 14.): however, see Discussion. Persons directly disturbing waterbirds (e.g., by entering the fishponds or approaching nests closely) were also relatively uncommon, but it is unclear how much the author's presence deterred this activity, since many of the regular park users from 1992 through 1995 were familiar with the author.

BOTULISM

During 139 censuses done at Kaloko Fishpond during this study, no Hawaiian Coots and only 1 duck (Table 1) were seen there. However, use of Kaloko Fishpond by Hawaiian Stilts increased to 2.1 $\pm$ 3.8 SD Stilts per census (n = 49) during the 1994 botulism year, in contrast to a mean of 0.3 $\pm$ 0.8 Stilts per census (n = 82) from Jan. 1992 through July 1993. No waterbirds or shorebirds were found dead at Kaloko Fishpond from avian botulism.

On 7 January 1994, just prior to the botulism die-off, the Hawaiian Coot count at 'Aimakapa Fishpond was the highest for all my counts (103 Coots), plus a high count of 145 migratory ducks. The Coot population at 'Aimakapa Fishpond reached its lowest level in November 1994, with a count of 0, but had recovered to pre-botulism levels by December 1995 (Fig. 4).

From February 1992 through early 1995, no waterbird nests were found in Kaloko Fishpond. Hawaiian Coot nests and eggs were not found in 'Aimakapa Fishpond from January to April 1994 during the botulism outbreak, even though Hawaiian Coots normally breed year-round (Shallenberger 1977, Morin pers. obs.). Although there were fewer nests, Hawaiian Stilts continued to nest and breed normally in 'Aimakapa Fishpond from March through July 1994. The number of fledgling Stilts per nest in 1994 was not significantly different from a pre-botulism year (1993).

DISCUSSION

WATERBIRD POPULATION CENSUSES

Migratory Ducks

Although from 1970 to 1980, Northern Pintails were reported to be the most abundant over-wintering duck on Hawai'i Island (Paton *et al.* 1984), the most abundant migrant ducks at 'Aimakapa Fishpond during this study were Northern Shovelers. Only non-zero duck counts were used to construct the mean number of ducks per count because the migratory ducks tended to stay flocked, and a duck count of zero during the over-wintering season usually meant the ducks were at some other nearby wetland. Counts of less frequently seen ducks, such as American Wigeon, tended especially to remain the same from count-to-count within any given season, suggesting that these were the same ducks as those counted previously, and that they were over-wintering at 'Aimakapa Fishpond and its associated wetlands, rather than simply passing through during migration. Although average migratory duck counts are not directly comparable during 1992 through 1995, due to sampling problems (e.g., counts from early 1992-1993 season, and early 1993-1994 season were not made, and too few counts from 1994-1995), counts from 1994-1995 season strongly suggest that the botulism die-off from the previous spring had negatively impacted the migratory ducks that typically over-winter at 'Aimakapa Fishpond. This observation tends to confirm the 1950s banding studies (Medeiros 1958) that showed Northern Pintails and Northern Shovelers returned in subsequent years, and were not merely vagrants. Not only was the average migrant duck count very low (9.2 ducks per count, versus 25.0 to 56.7 ducks per count for the other years: see Fig. 3) but the composition of the ducks present may have changed, perhaps due to differential susceptibility of the duck species to botulism. The most obvious difference was the complete absence of Scaup and the presence of a single Pintail: both species are typically present in small numbers each year.

Migratory waterfowl (except for one duck on one occasion) were not seen at Kaloko Fishpond during this study, probably mainly because the duck species that migrate to the Hawaiian Islands cannot tolerate the higher salinities, such as those found in Kaloko Fishpond. They prefer fresh or mostly fresh water. Also, the vegetation and associated invertebrate fauna found at Kaloko Fishpond is inappropriate for fostering feeding or providing escape cover. See discussion below under Hawaiian Coots.

Hawaiian Coots

During the 1980's as many as 188 Hawaiian Coots were reported from Aimakapa Fishpond (Jaan Lepson, unpubl. data). Hawaiian Coots were not seen using Kaloko Fishpond during the 139 censuses made there during this study. Like migratory ducks, the Coots prefer fresh or mostly fresh water, and salinities in Kaloko Fishpond are significantly higher than salinities at

'Aimakapa Fishpond. Especially for nesting, Coots are associated with grass and sedge vegetation, although high levels of invertebrate food will attract them to open freshwater bodies for feeding (e.g., the sewage ponds south of KAHO).

During the earliest counts (1992), red mangrove was still being removed at Kaloko Fishpond and human disturbance was high. After the mangrove was gone, alien pickleweed or 'akulikuli kai (*Batis maritima*) rapidly invaded the open mudflats and choked out most of the remaining native vegetation. Unmanaged *Batis* is inappropriate Coot habitat, since its' final growth form in KAHO wetlands was tall (at least 2/3 meter), dense, and tangled, making movement through it extremely difficult or impossible, especially for birds.

Hawaiian Stilts

Nesting and fledging success appeared to increase after predator control was initiated at 'Aimakapa Fishpond in 1993, and the probable population increase helped to buffer the loss of a few Stilt to botulism in the following year. Hawaiian Stilt use at Kaloko Fishpond increased after mangrove removal, and especially once the few islets and test plots were cleared of pickleweed, providing the Stilts with mudflats that they prefer for foraging. Stilts could almost certainly nest successfully at Kaloko Fishpond, if at least some mudflats were kept cleared of the non-native pickleweed, if a few nesting islets or floating platforms were available and maintained for nesting, and if predator control was done around the fishpond's perimeter.

Other Migrants and Resident Waterbirds

KAHO's wetlands are a major "migrant trap" for Hawai'i Island, and provide needed habitat for overwintering waterbirds and shorebirds. Many visiting bird-watchers are more interested in the numerous migrant and vagrant bird species than in the endemic endangered species, especially because unusual species from Asia and other parts of the Pacific infrequently stop in the Hawaiian Islands.

Although Blue-winged Teal are considered an "occasional to frequent" migrant to the Hawaiian Islands (Pyle 1997), and bred at 'Aimakapa Fishpond in 1982 and 1983 (Paton *et al.* 1984), they no longer breed there or elsewhere in the Hawaiian Islands. They appear to have been unsuccessful (this time) in colonizing the Hawaiian Islands. Another migrant, the Pied-billed Grebe, which used to be considered an "accidental straggler" (Paton and Scott 1985), has, in the short term, seemingly become established at Aimakapa Fishpond after a single pair successfully nested there in 1985. Whether or not it can persist remains to be seen, especially because the Pied-billed Grebes at 'Aimakapa are almost certainly highly inbred.

The Sewage Treatment Plant, operational since approximately spring of 1994, and located just south of KAHO, appears to have either concentrated the native Black-crowned Night-Heron or 'Auku'u population in west Hawai'i, or to have allowed the population to expand due to its abundant invertebrates. This has occurred since 1995, when this study ended, and the impact of such a high 'Auku'u population might have a significant negative impact on endangered waterbird reproduction at nearby more natural sites (e.g., 'Aimakapa) since 'Auku'u are believed to sometimes prey on waterbird chicks.

WATERBIRD REPRODUCTION

Breeding Season

Chang (1990) reported that the nesting season for Hawaiian Stilts at his study site on O'ahu was March through July (plus one nest apparently initiated in September) and that nesting peaked in May. Coleman (1981) reported that at his study site on O'ahu, stilt nesting occurred between mid-February through late August, with peaks (either March or May) that varied slightly among the three years of his study. At 'Aimakapa Fishpond, March, April, and June were apparently the most favored months (Table 2). I suspect that most of the June nests were second nests or renests of failed nest attempts, and that the peak in March and April represents the initial nest attempts for most or all Stilt pairs at 'Aimakapa.

No Stilt nests with eggs were found in 1992, although nest scrapes and appropriate pair behavior were observed. A predator control trap line was not initiated around 'Aimakapa until early 1993, and artificial platforms were not placed in the fishpond until very late 1992 and early 1993. The Stilts seemed to prefer wooden platforms, which are relatively safe from terrestrial predators. The Stilts also nested heavily along the north shore of 'Aimakapa Fishpond, which was "patrolled" by mongooses prior to the trapping effort.

The nesting season for Hawaiian Coots reported by Chang (1990) peaked from February through May but occurred year-round in every month except November. Interestingly, I also did not find any coot nests in November (or January) but found them in all other months. Coleman (1978) reported breeding peaks at Kakahai'a, Moloka'i, from November through February and June through October. Shallenberger (1977) reported that Coots nested year-round.

In the botulism year of 1994, no Coot nests were found from January through April when mortality was high, although Stilts did initiate nests during that time period.

Because of unsuccessful reproduction (Table 7b), the year-round nesting by the Pied-billed Grebes is probably attributable to the same pair or few pairs continuously renesting. Elsewhere in the Northern Hemisphere, egg dates are reported to be April and May (Harrison 1983).

Nest Site Placement

Examination of Fig. 14 clearly indicates that most of the endangered Coot and Stilt nests were built on the eastern half of 'Aimakapa Fishpond. The vast majority of visitor use in the areas was concentrated on the berm at the western shore. It is very likely that the constant activity on the western shore inhibited endangered waterbird use on that shoreline, and especially inhibited any nesting attempts that could have resulted in eggs. Definite conclusions are confounded by the fact that the eastern half of 'Aimakapa is physically different from the western side, having numerous rockwalls, islets, and more "visual" cover (areas screened by vegetation). However, it is likely that more visitor activity on the northern, southern, and eastern shores of 'Aimakapa would negatively impact not only waterbird feeding but also disrupt nesting to an unknown degree.

Both Stilts and Coots built nests on the shoreline and rockwalls, although Stilts were more likely to build at easily accessible (to human and dogs) shoreline sites. In addition, Stilt nests are usually not visible to untrained human eyes, since a true nest is not usually built, and the eggs are camouflaged with brownish splotches. Stilts must have access to mudflats for their chicks to forage and survive, since their young feed themselves after hatching. Each Stilt nest

was adjacent to, or very close to a mudflat. Siltation in 'Aimakapa has created numerous mudflats, and any attempts to "flush" the fishpond (e.g., by opening the makaha) might seriously degrade the ability of 'Aimakapa to provide adequate foraging sites for flightless Stilt chicks (flightless for approximately the first month of life).

Clutch Size

Stilts are determinate layers where clutch size is rigidly "set" and coots are considered to be indeterminate layers with much more flexibility in clutch size. For Hawaiian Stilts, Chang (1990) reported an average clutch size of 3.4 eggs (n=243 nests), and Coleman (1981) reported an average clutch size of 3.6 eggs (n=366 nests). The average clutch size in this study is identical to Chang's finding. Because Stilts are determinate layers and the modal clutch size is 4 eggs, smaller clutches should be viewed as cases where other problems (e.g., undocumented predation) possibly occurred.

Both Chang (1990) and Byrd *et al.* (1985) reported an average Hawaiian Coot clutch size of 4.9 eggs (n=138 and n=33, respectively). This study found the average clutch size of Hawaiian Coots to be 5.0 eggs per nest (Table 6a.), which is basically the same as theirs. However, the most common clutch size in this study was actually 6 eggs (Fig. 16), and larger clutches were not uncommon. In general, the closely related American Coot (*Fulica americana americana*) has larger average clutch sizes, with approximately 8 eggs per clutch (Byrd *et al.* 1985). It is noteworthy that although the Coots had larger clutches than Stilts, they had lower fledging success at 'Aimakapa.

Fledging

Fledging success, not egg production, is really the criterion that should be used to evaluate success or failure of different management activities. The Coots at 'Aimakapa were a good example of this, since egg production was steady but few fledgling Coots were produced.

No Hawaiian Stilts nests with eggs, and hence no chicks or fledglings, were found in 1992 although what looked liked typical nest scrapes were located and appropriate pair behavior was seen. This was at least partially due to the fact that predator control was not undertaken until 1993. Although 1993 and 1994 fledglings per Stilt nest (Table 5b.) may appear to be low relative to other studies, they probably are not: compare 0.9 and 1.6 fledglings per nest to 1.9 chicks per clutch (Chang 1990) and 2.0 chicks per clutch (Coleman 1981). These latter two studies reported chicks rather than fledglings, and thus do not include chick mortality that occurs within the first month of life.

The number of fledglings per Coot nest seems low (Table 6b.), and did not seem to improve in 1993 after predator control was initiated. Chang (1990) reported 3.2 chicks per brood, but apparently these were hatchlings, not fledglings. Over the three years of this study, less than one (0.73) offspring was produced per Coot nest attempt. The many large fish in 'Aimakapa Fishpond, of unknown variety and number, may be responsible for the poor Coot recruitment, especially because clutch sizes are well within the normal range.

The apparent decrease in fledglings per nest for coots in 1994 is due to the botulism outbreak. Most of the Coots at 'Aimakapa Fishpond eventually died, and ones that nested were possibly experiencing "toxic" symptoms. In 1994, unlike other years where year-round Coot breeding occurred, no Coot nests with eggs were found in 'Aimakapa until May. Conversely,

Hawaiian Stilts appeared to have slightly better fledging success in 1994 (Table 5b.), although it was not statistically significant!

Nests Substrates and Nest Outcomes

Hawaiian Coot nests are elaborate structures; although the Coots often try to conceal them by placing nests in hidden areas or in somewhat dense (but not too dense) cover. Coot nests are quite obvious at close proximity. Hawaiian Coots are generally reported to build floating or semi-floating nests anchored near or in emergent vegetation (Byrd *et al.*1985, Schwartz and Schwartz 1952). At 'Aimakapa, Coot nests were most commonly built on small natural islets (Table 4). This can be a risky choice because, depending upon its height, the islet confers little protection from tidal extremes and storm surges in the fishpond. High water destruction to the nest was the most frequent cause for Coot nest failure (Tables 8 and 9). Even though islets were the substrate most frequently chosen by Coots, nesting on an islet resulted in a fledging rate lower than either the floating platform or the shoreline (Table 12). However, no Coot nests were found on the shoreline in 1992 prior to the predator trapping, and both Coot nests known to fledge young in 1992 were located on islets. It is likely that the better fledging from shoreline nests in later years is a direct result of the predator control; without it, the likelihood of a Coot successfully fledging young from a shoreline nest is small.

In contrast to Coot nests, Hawaiian Stilts generally build little or no nest, although the author has seen exceptions to this rule and Stilts display great flexibility in this regard. Stilts prefer to have little or even no cover surrounding the nest (Coleman 1981), presumably so that their view for spotting predators is not obstructed. They rely heavily on the cryptic nature of their nest (e.g., often no nest structure at all) and the camouflaged egg coloration. However, no Stilt nests with eggs were located in 1992 prior to predator control, which is probably not too surprising since no floating platforms (the most frequently chosen substrate in 1993/1994) were yet in place and shoreline nesting (the second most frequently chosen substrate in 1993/1994) would have undoubtedly had a low success rate. Although they were not chosen as often as nest substrates, Hawaiian Stilts fledged the most chicks per nest from islets and rockwalls (Table 12). For nesting, Stilts preferred artificial platforms, the shoreline, and floating vegetation mats, in that order (Table 4). The immediate acceptance of floating platforms by the Stilts and observations of pairs frequenting islets but seldom nesting there suggest that Coots outcompete the Stilts for islet nest sites.

Excluding grebe nests, the overall most used substrates for coot and Stilt nests were natural islets (n = 20, mostly Coots). The second most used was floating vegetation mats (n = 18), and artificial platforms, rockwalls, and the shoreline were all used equally (n = 11 for each category; Table 4). Clearly, these species differences show how carefully management must be undertaken in order to accommodate both species' diversified needs.

ARTIFICIAL FLOATING NEST PLATFORMS

Even though no floating platforms were available for use in 1992, Stilts most frequently chose wooden floating platforms as a nest substrate (Table 4). Hawaiian Coots also accepted the wooden platforms as nest substrates, although clearly preferred islets (Table 4). Hawaiian Stilts frequently alighted on the islets, and appeared to do nest intention behavior, but it appeared that Coots were better able to obtain and hold islets as nest substrates. Floating platforms are an artificial approximation of an islet, and both floating platforms and islets conferred some protection not only against high water damage to the nest, but also to predation from terrestrial vertebrates (e.g., mongooses and cats).

Floating platforms were insufficiently anchored to withstand extreme high tides, strong surf (especially in Kaloko Fishpond), or heavy winds. The dowels were strong enough to hold the platforms during typical weather, but were not embedded deeply enough in the mud to withstand extreme conditions. Several platforms became loose and floated away to different sites within the ponds during extreme storm surge. If an adequate, more permanent anchoring system could be devised (e.g., cable with swivels attached to a heavy rock, or mooring pin embedded in the underlying pahoehoe lava), the floating platforms could be an effective method of protecting nests from predation, and also reducing nest loss due to high water. High water was the most frequent identified cause of nest loss for Hawaiian Coots during this study, and one of the two most frequent causes of nest loss for Hawaiian Stilts (Table 8).

PREDATOR CONTROL

The two trap-and-release small mammal density grids (one done in the vegetation behind Kaloko Fishpond and one done behind 'Aimakapa Fishpond) indicated that there were large, mobile populations of mongooses in KAHO (Morin pers. comm.). Trapping around 'Aimakapa Fishpond indicated that as mongooses were removed, others expanded their ranges or migrated in to fill the vacated territories. The fact that no endangered Stilt chicks were known to fledge in 1992 prior to predator control, and that Stilts fledged in 1993 and 1994 during predator control, indicates that removal of mongooses and cats has a beneficial effect on Stilt chick survival and recruitment.

It is not appropriate to use pesticides which cause delayed predator mortality in wetlands like 'Aimakapa. Dead carcasses of predators that have died at unknown sites in the wetland can trigger waterbird botulism outbreaks. Live trapping, euthanasia, and appropriate carcass disposal (ideally incineration, or covered disposal at legal animal carcass disposal sites) away from the wetland should be the technique of choice.

Although rats were not specifically targeted during predator control, their presence in the traps indicates that the effects of rat predation on Stilt and Coot recruitment should be investigated.

Cats and dogs, both feral and pets, are present at KAHO and create an on-going waterbird predation and harassment problem. Proximity to Honokohau Harbor increases the presence of cats and dogs in the Park, and almost certainly provides an abundant food source (via trash) for maintaining mongoose and rat populations.

Two groups of possible predators need continued surveillance and future study: fish and other waterbirds. The large fish present in 'Aimakapa Fishpond are suspected to be predators on Coot chicks (Morin pers. obs.). It is also possible that reported large fish in Kaloko Fishpond limit waterbird use there. The native Black-crowned Night-Heron and the non-native Cattle Egret have both been implicated elsewhere as predators on waterbird chicks, and hence their populations and activities in or near KAHO should be carefully monitored. The recent rapid expansion of Black-crowned Night-Herons at the Sewage plant just south of Honokohau Harbor is a situation that warrants future study; population control for 'Auku'u and/or Cattle Egrets, or actively hazing them away from endangered waterbird breeding sites at 'Aimakapa, may need to be initiated someday.

One feral pig (approx. 100 lbs) was removed from the wetlands surrounding 'Aimakapa Fishpond. It left considerable sign (rooting damage, footprints, and feces) for an extended period before it was successfully removed. In 1994 and 1995, other piglet footprints were seen

in the coastal strand vegetation near the permittee's houses, which have since been removed. It is unclear what the source of those pig(s) was and whether they are still present.

WETLAND VEGETATION MANAGEMENT

Red mangrove is an invasive non-native wetland plant that can rapidly grow and fill in wetlands of varying salinities. It was first introduced to the Hawaiian Islands in 1902 by the American Sugar Company (Wagner *et al.* 1990), and has rapidly expanded its range. Prior to removal, mangrove had probably been established in Kaloko Fishpond for only about 20 to 40 years, based on past records of waterbird use at Kaloko Fishpond that would have been incompatible with dense mangrove infestation.

The initial invasion of non-native mangroves at KAHO was probably seeded from the older mangrove population at the popular site locally called "Pine Trees", which is north of KAHO. Mangrove seeds will float in water, and retain viability in salt water, so regular ocean movements bring the buoyant seeds to the Park's shoreline. Especially during winter storms and high surge, viable seeds can float not only into both fishponds but also far enough inland to reach anchialine pools within KAHO. Although mangrove has mostly been removed from KAHO at present, as long as the mangroves remain at "Pine Trees" KAHO will have to routinely remove mangrove seedlings and vigilantly survey the Park to prevent reinvasion.

By the time control was begun, the density of mangroves at Kaloko Fishpond had outcompeted most native vegetation. The mudflats laid bare by mangrove removal were rapidly invaded by another nonnative, pickleweed or 'akulikuli kai (*Batis*), which has since densely established itself over most of Kaloko Fishpond's mudflats and shoreline. A quick planting of native makaloa (*Cyperus laevigatus*) plugs and the native 'akulikuli (*Sesuvium portulacastrum*) might have prevented or reduced the pickleweed invasion.

The periodic clearing (primarily of nonnative plants) done especially on islets and protected mudflats (e.g., the southeast "finger" of Kaloko Fishpond) showed that reestablishment of native vegetation can be accomplished after hand-clearing without pesticide use, if the site is revisited and periodically stripped of pickleweed sprouts. KAHO is currently experimenting with scorching pickleweed to cause it to dieback, and having preliminary success with this tactic. One recurring problem with hand-clearing and scorching is the proper education of workers to distinguish among three similar species: the alien pickleweed, and two similar natives: 'ohelo kai (*Lycium*) and 'akulikuli (*Sesuvium*), of which the latter two should remain undisturbed.

Much of the wetland areas next to 'Aimakapa Fishpond are apparently silted-in parts of the fishpond (Fig. 2). Some mostly buried rockwalls can be located from aerial photographs and relocated on-the-ground, indicated by the linear growth patterns of milo and hau trees. A gradual removal of vegetation and possibly a conservative amount of silt removal could expose these buried sections, and provide additional open shallow water and mudflat sites for waterbird feeding and nesting.

VISITOR NUMBERS AND ACTIVITIES NEAR FISHPONDS

Visitor and dog counts were made as an afterthought relative to bird censuses, and different times of day were not equally sampled. Using paired counts is an attempt to control some variables so that comparisons between the two fishponds are more valid. However, early morning and late afternoon are not adequately represented. Because of this unequal sampling, some activities (such as bird watching, which might show up in the TOO CLOSE category, and

fishing) are probably underrepresented, since they are more likely to be done in the early morning hours or evening hours.

Dogs in KAHO apparently declined after the leash policy in the Park was begun in 1994 (Table 13). Although some feral dogs were seen in KAHO, owners brought most dogs for the express purpose of running them on the beach and in the water. Most of the dogs were large dogs of retriever, Labrador, or German shepherd size and type; many of these dogs enjoyed swimming and were not opposed to chasing birds. Fewer dogs were brought after the six-foot leash policy was instigated because the dogs were restricted in their movements, and running the dogs was one of the reasons that owners brought their dogs. In spite of the fact that some owners had voice control over unleashed dogs, many and possibly most owners did not. Hawaiian Stilt chicks are extremely vulnerable to any kind of disturbance and predation during their unflighted growth phase (approximately a month after hatching). During that time interval, Stilt chicks forage along the shoreline mudflats and hide motionless in the grass whenever disturbed. In addition to being very vulnerable to being accidentally stepped on, any good bird dog should be able to detect a hidden stilt chick, given enough search time. Also, nesting adult Hawaiian Coots and Stilts are extremely vulnerable to predation during the incubation phase, and shoreline nests or near shore nests could easily be depredated by dogs. One presumably feral dog was shot by a Park Ranger after it was determined that the dog was in the fishpond harassing an actively nesting Hawaiian Stilt.

Visitor use appears to have steadily increased near Kaloko Fishpond from 1992 through the beginning of 1995 (Table 15.). The high Park personnel numbers at Kaloko Fishpond in 1992 and 1993 are due in part to the ongoing mangrove removal project during those years, and also to the parking lot restoration work done after a high tide episode moved the restroom and damaged the rock walls and parking area. Based on these counts, visitor use (after excluding Park personnel counts) at Kaloko Fishpond increased from approximately 15% of the use at 'Aimakapa Fishpond in 1992 up to approximately 20% to 33% (4 to 7 visitors per count) of the use at 'Aimakapa Fishpond in 1994 and 1995. Visitor use (excluding Park personnel) at 'Aimakapa beach remained relatively constant at about 20 visitors per count. The beach next to 'Aimakapa Fishpond was a very popular clothing-optional sunbathing beach up until Park policy was changed in 1997. It is unclear whether visitor use should increase or decrease after closing the beach to nude sunbathing.

BOTULISM AND OTHER AVIAN DISEASES

Avian disease is always a potential problem, but there are important management activities that can keep KAHO's waterbirds safer. Clearly, disease and parasites can always arrive at KAHO via migratory birds, but fortunately there is a self-limiting mechanism that provides some protection. The lengthy migration required to reach the Hawaiian Islands usually means that sick birds would probably not be able to finish their migration.

Domestic fowl, such as ducks or geese from captive sources, pose a bigger problem. Indeed, the original records of botulism-like disease on Hawai'i Island occurred in 1987 in semi-captive waterfowl flock north of Kona (Morin 1996d) which free-ranging native and indigenous waterbirds could have visited. Other avian diseases such as avian tuberculosis could be transmitted via wild free-ranging waterbirds that visit open penned captive waterbird flocks.

The immediate removal and proper disposal of carcasses (fish as well as predators and birds) is the primary and essential management activity necessary to prevent another botulism outbreak.

CONCLUSIONS AND RECOMMENDATIONS

WATERBIRD POPULATIONS

1)Waterbird and shorebird use at Kaloko Fishpond would increase with appropriate wetland management, such as reducing the influx of ocean water and removing pickleweed, while revegetating with native plants like 'akulikuli, 'ohelo kai, and makaloa and maintaining some open mudflats.

RECOMMEND THAT THE SEAWALL AT KALOKO FISHPOND BE CONSIDERED FOR REBUILDING, PARTLY WITH THE INTENT TO LOWER THE FISHPOND'S SALINITY. SALINITY IN KALOKO IS HIGH PARTLY DUE TO MASSIVE DIRECT CONTACT WITH THE OCEAN WATER, WHICH OVERWHELMS THE FRESHWATER INFLOWS FROM UPSLOPE.

WATERBIRD REPRODUCTION

1) The absence of Hawaiian Stilt eggs in 1992 prior to predator control and the presence of fledglings in 1993 and 1994 during predator control suggests that predator control should be a baseline management activity at 'Aimakapa Fishpond. RECOMMEND THAT PERMANENT PREDATOR CONTROL BE DONE AROUND AT LEAST 'AIMAKAPA FISHPOND'S PERIMETER, AND ALSO AROUND KALOKO FISHPOND IF OTHER WATERBIRD MANAGEMENT OCCURS THERE. PREDATOR CONTROL SHOULD OCCUR FROM AT LEAST LATE JANUARY THROUGH THE END OF AUGUST EACH YEAR AND PREFERABLY SHOULD OCCUR YEAR-ROUND IF FUNDING PERMITS.

2) Heavy loss of Coot nests to high water, combined with high chick mortality possibly caused by large fishes within 'Aimakapa Fishpond, seemed to be the two major limiting factors for Coots, which clearly preferred to nest on islets. Stilts appeared to have their best fledging success from islet nests. THE POSSIBILITY OF ADDING ANOTHER FOOT OF HEIGHT TO ISLETS WITHIN BOTH FISHPONDS SHOULD BE SERIOUSLY EXAMINED. ADDITIONAL ISLETS SHOULD BE BUILT IF POSSIBLE. ISLETS WITH DENSE BRUSHY VEGETATION OR NONNATIVE PICKLEWEED SHOULD BE HAND-CLEARED YEARLY IN LATE DECEMBER OR EARLY JANUARY SO THAT THEY BECOME AVAILABLE AS NEST SITES. (SEE ALSO "VISITOR NUMBERS AND ACTIVITIES NEAR FISHPONDS" SECTION BELOW.)

ARTIFICIAL FLOATING NEST PLATFORMS

1) Certain floating platform designs are definitely accepted by both Hawaiian Stilts and Coots, but especially by the Stilts. The occasional dislodgment and movement of platforms due to high tides and storm surge are problems that need to be resolved. Not only do platforms function as predator deterrents and protection from high water damage, but they also reduce the possibility of human interference with shoreline nests.

FLOATING WOODEN PLATFORMS SHOULD BE PROVIDED AND MAINTAINED IN 'AIMAKAPA FISHPOND, WITH CONTINUING RESEARCH INTO THE BEST ANCHORING METHOD. FLOATING WOODEN PLATFORMS SHOULD BE PROVIDED AND MAINTAINED IN KALOKO FISHPOND ONCE SHORELINE VEGETATION MANAGEMENT HAS PROVIDED MUDFLATS FOR CHICK FORAGING SITES AND IF PREDATOR CONTROL IS ONGOING AROUND KALOKO FISHPOND.

PREDATOR CONTROL

1) Predator control appears to have contributed to the successful reproduction of Hawaiian Stilt at 'Aimakapa Fishpond (see Waterbird Reproduction above). Although predator control has probably expanded the types of nest sites available to Hawaiian Coots (e.g., shoreline), it does not seem to have increased the fledging rate per nest although it possibly increased the total number of nests and apparently increased the number of Coot nests on the shoreline.

RECOMMEND TRAP-AND-REMOVE (NON-TOXICANT) PREDATOR CONTROL BE DONE ALONG 'AIMAKAPA FISHPOND'S PERIMETER YEAR-ROUND, SINCE HAWAIIAN COOT NESTING IS YEAR-ROUND. RECOMMEND PREDATOR CONTROL BE EXPANDED TO KALOKO FISHPOND'S PERIMETER WHEN OTHER WATERBIRD HABITAT RESTORATION BEGINS THERE.

2) A systematic survey of fish species, sizes, and numbers should be done at Aimakapa during the Stilt non-breeding season (approximately September to January) combined with Coot family observations in order to determine if fish are predating chicks and should be removed. If it is verified that fish should be removed, removal methods should be designed to cause very limited waterbird disturbance. Once the seawall at Kaloko Fishpond has been rebuilt, and if the salinity is reduced and appropriate shoreline vegetation management (i.e. restoration of preferred Coot plants) has been initiated, a similar survey should be done there.

RECOMMEND STUDY AND POSSIBLE REMOVAL OF LARGE FISH IN AIMAKAPA FISHPOND THAT MAY BE EATING YOUNG WATERBIRD CHICKS, ESPECIALLY COOT CHICKS, WHICH FEED BY SWIMMING IN THE WATER RATHER THAN FEEDING ON THE SHORE.

3) Recent 'Auku'u populations at the Sewage Plant are high and might pose a hazard to 'Aimakapa waterbirds. Cattle Egrets continue to visit KAHO in small numbers. The status of pigs in KAHO is subject to change serendipitously, but is most likely caused by humans releasing them into the area. Rats pose an unknown amount of risk to endangered waterbird breeding at 'Aimakapa and Kaloko Fishponds.

RECOMMEND CONTINUOUS EVALUATION OF BLACK-CROWNED NIGHT-HERONS, CATTLE EGRETS, PIGS, AND RATS AS POTENTIAL PREDATORS ON ENDANGERED WATERBIRD NESTS. OBTAIN APPROPRIATE ADVICE AND FEDERAL AND STATE PERMITS PRIOR TO UNDERTAKING ANY CONTROL ACTIVITY.

WETLAND VEGETATION MANAGEMENT

1) RECOMMEND CONTINUOUS REGULAR INSPECTION OF ALL WETLAND AREAS IN KAHO FOR REINVASION BY MANGROVE. RECOMMEND IMMEDIATE ERADICATION OF ANY MANGROVE FOUND DURING ROUTINE INSPECTIONS.

2) The nonnative pickleweed should be removed at Kaloko Fishpond and native plants such as makaloa and the native 'akulikuli replanted and/or allowed to spread. 'Aimakapa Fishpond needs to have invading plants monitored and removed (e.g., mangrove, pickleweed) as well as to have some areas slowly cleared of vegetation (primarily *Paspalum*) in order to reopen parts of the wetland, which have been slowly silting in. However, silt forms the mudflats essential to Stilt chick foraging.

VEGETATION MANAGEMENT SHOULD BE INITIATED AT ONCE AT BOTH FISHPONDS TO RESTORE WETLAND HABITAT AT KALOKO AND TO MAINTAIN WETLAND HABITAT AT 'AIMAKAPA.

VISITOR NUMBERS AND ACTIVITIES NEAR FISHPONDS

1) It is unclear whether closing 'Aimakapa beach to clothing-optional sunbathing will increase or decrease visitor use, although probably it will be the former. Attractive, discrete signs at the top of the sand berm at 'Aimakapa Fishpond and near the visitor kiosk at Kaloko Fishpond should describe the endangered waterbirds very briefly and also state that dogs are not allowed in the wetlands.

RECOMMEND DISCRETE SIGNAGE AND BROCHURES TO EDUCATE THE PUBLIC ABOUT APPROPRIATE ACTIVITIES AT ENDANGERED WATERBIRD WETLANDS AND ESPECIALLY DURING THE STILT BREEDING SEASON.

2) Due to their serious potential for harassment, dogs should never be allowed in the fishponds or wetlands where the endangered waterbirds forage and nest, and should only be allowed in the Park if maintained on a short leash under control of the owner. Adequate signs at KAHO entrance points should inform visitors about the leash policy, so that dog owners see the information before getting to the wetlands and fishponds. Reasons for the leash policy should be clearly explained on the signs and in Park brochures describing the endangered waterbirds and their habitat.

RECOMMEND DOGS BE EXCLUDED FROM FISHPONDS AND WETLANDS WITH ENDANGERED WATERBIRDS, AND LEASHED ELSEWHERE IN THE PARK. RECOMMEND VISITOR BROCHURES (see # 1 above) EXPLAIN DOG RESTRICTIONS.

3) If not already in place, KAHO should develop a policy that no swimming or boats, kayaks, wave skis, or canoes are allowed in the fishponds. KAHO and State Div. of Aquatic Resources should carefully develop a policy on types of acceptable fishing and acceptable numbers of fisherpersons. Fishing line, which entangles waterbird and shorebird legs and can cause mortality, is already routinely found at Kaloko Fishpond. Very small amounts of fishing or boating (e.g., one person per day for one hour) would not excessively disturb the waterbirds, but boaters or fisherpersons disrupting waterbird feeding and resting several times a day would certainly become a serious disturbance problem, especially during nesting season. Most persons would not be interested in swimming in the fishponds due to the relatively smelly, murky water ('Aimakapa) and sharp oyster shells (Kaloko Fishpond) and the presence of stinging fire worms (Family Amphinomidae: Thomas and Scott 1997). However, many visitors from the mainland and from other parts of Hawaii State are not familiar with these hazards, and prohibitions against swimming and boating, and fishing regulations for fishponds should be clearly stated in KAHO brochures and on discrete signs next to the fishponds.

RECOMMEND KAHO DEVELOP A POLICY THAT PROHIBITS SWIMMING AND BOATING IN THE FISHPONDS, AND A CONSERVATIVE POLICY ON FISHING IN THE FISHPONDS.

4) 'Aimakapa Fishpond is listed in Pratt's (1993) popular birding guide as "...one of Hawaii's most important and accessible birding localities. Don't miss it." At least one bird tour group being led by a major international ecotour group has visited 'Aimakapa Fishpond which had not checked in KAHO headquarters. Certainly some of the now numerous ecotour companies in

Kona could or do provide birding tours to KAHO's wetlands. Birding tour groups are some of the most likely visitors to actually enter and disturb the waterbird feeding and nesting areas. It is likely that organized ecotour activities within KAHO will increase over time.

RECOMMEND KAHO DEVELOP A POLICY ON REGISTRATION OF AND GUIDANCE FOR COMMERCIAL AND GROUP ECOTOUR ACTIVITIES AT THE FISHPONDS AND OTHER WETLANDS (E.G., ANCHIALINE POOLS). AS HAS ALREADY HAPPENED ON MANY STATE TRAILS, IT IS LIKELY THAT IN THE NEAR FUTURE THE NUMBER OF ECOTOUR GROUPS USING A PARTICULAR SITE AT KAHO MAY HAVE TO BE REGULATED AND POSSIBLY RESTRICTED.

5) 'Aimakapa Fishpond and the perimeter immediately around 'Aimakapa Fishpond (at least 45 meters on north, east and south sides and 10 meters on the west side) should be closed to vehicle and foot traffic except for authorized Park personnel or persons accompanied by or supervised by authorized Park personnel and only on a limited basis. Not only can humans or vehicles cause direct nest and egg destruction by stepping on nests or continuously causing adult breeding birds to abandon their egg incubation or feeding, but the negative impact of continuous human disturbance even to non-breeding waterbirds should not be underestimated and can cause site abandonment over time. Young flightless Hawaiian Stilt chicks crouch motionless when alarmed, and can easily be stepped on by humans. Not only are the chicks cryptically colored to match natural surroundings, but also they will hide under thick vegetation when possible, which makes them even more difficult to detect and more vulnerable to being stepped on.

RECOMMEND NO TRAILS OR PERMANENT BUILDINGS BE BUILT IMMEDIATELY ADJACENT TO THE FISHPONDS. THE USE OF RAISED, DISTANT, FENCED BOARDWALKS (E.G., ON UPPER LEVEL OF LAVA FLOW EAST OF 'AIMAKAPA FISHPOND) AND SPOTTING TOWERS EQUIPPED WITH SPOTTING SCOPES WILL MINIMIZE BREEDING AND FEEDING BIRD DISTURBANCE, AND ALLOW FOR OPTIMAL VIEWING OF BIRDS. THESE PRECAUTIONS WOULD PREVENT WATERBIRDS FROM BEING CONTINUOUSLY FLUSHED BY TOO-CLOSE VISITORS.

BOTULISM AND OTHER AVIAN DISEASES

1) Carcass removal of dead fish, birds, and other animals from fishponds and surrounding wetlands should continue on a regular basis in order to reduce the likelihood of another botulism outbreak. Carcass removal can be done during regular population monitoring. Inspections should be done every other day if no carcasses are found, and daily for at least a week after a carcass is found.

RECOMMEND CARCASSES BE REGULARLY SEARCHED FOR AND IMMEDIATELY REMOVED FROM WETLANDS AND PROPERLY DISPOSED OF OUTSIDE WETLAND AREAS.

2) Carcasses can begin botulism outbreaks if botulinum toxin is produced under anaerobic conditions, such as within a dead body.

PREDATOR CONTROL IN OR NEAR WETLANDS AND FISHPONDS SHOULD NOT USE TOXICANT BAITS THAT ARE INGESTED BY ANIMALS WHO LATER COULD DIE AT UNDETECTED LOCATIONS WITHIN WETLANDS.

3) Domestic waterbirds may introduce new diseases or internal parasites to the resident native and migratory indigenous waterbirds and shorebirds, or become established and compete with native and indigenous waterbirds for food and nest sites.

RECOMMEND ANY DOMESTIC WATERBIRDS INTRODUCED INTO KAHO'S WETLANDS, EITHER DELIBERATELY BY HUMANS OR ACCIDENTALLY BY DISPERSAL FROM OTHER SITES, SHOULD BE REMOVED AS QUICKLY AS POSSIBLE AFTER CONSULTING WITH APPROPRIATE STATE AND FEDERAL BIOLOGISTS.

4). The usefulness and possible outcomes of reopening the makaha at 'Aimakapa should be evaluated very carefully. Only if the low salinity (currently the fishpond water is only slightly saltier than ground water) can be maintained and the amount of mudflats needed by Stilt chicks not drastically reduced, does reopening the makaha might make sense. Removal of small amounts of siltation can be accomplished by other means than reopening the sluice gate. Altering the fishpond salinity (even temporarily) would alter the salt-tolerant (but not salt-loving) vegetation, as well as cause Coots and migratory waterfowl to abandon the site because both dislike salt water. Invertebrate die-offs from salinity changes could even trigger a botulism outbreak.

RECOMMEND THAT THE MAKAHA (SLUICE GATE) AT 'AIMAKAPA NOT BE REOPENED, BUT IF CONSIDERATION IS GIVEN TO REOPENING IT, A MULTI-DISCIPLINARY TEAM STUDY SHOULD EVALUATE ALL THE RAMIFICATIONS TO THE WETLAND ECOSYSTEM AND TO PLAN WAYS TO REOPEN IT WITHOUT CAUSING DEGRADATION TO EXISTING WATERBIRD HABITAT.

5). Excessive water nutrient load, pesticides, or abrupt water quality or quantity changes can cause animal die-offs (including die-offs of invertebrates, fish, birds, or mammals). Decaying organic material increase the potential for bacterial growth and botulism toxin development (Clarke 1987, Jensen and Price 1987, Wobeser 1987).

RECOMMEND THAT WATER QUALITY WITHIN THE PARK AND ADJACENT LANDS BE CAREFULLY MONITORED, AND THAT PARK STAFF RECOMMEND AGAINST ANY DEVELOPMENT OR ACTIVITY PROPOSALS THAT WILL DECREASE WATER QUALITY IN THE FISHPONDS, ANCHIALINE POOLS, AND ASSOCIATED WETLANDS."

SUMMARY

There are already many changes to west Hawai'i's wetland and waterbirds situation since this study was finished in 1995. The Sewage Treatment Plant south of Honokohau Harbor has become a major waterbird feeding site, but although Stilts apparently try to nest there, predation precludes any use other than as a feeding site. Cyanotech has continued to expand its production of algae, and has built numerous "runway" ponds that attract not only shorebirds but also Stilts, which repeatedly try to nest next to these productive artificial ponds. Alien vegetation control and predator control at other wetlands in west Hawai'i still appears to be minimal or nonexistent. Much work remains to be done in order to adequately manage and maintain wetlands and waterbirds in west Hawai'i.

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Table 1. Waterbird and shorebird species and relative abundance from complete counts made at 'Aimakapa Fishpond (AP: n = 168 counts), Kaloko Fishpond (KP: n = 109 counts), and the shoreline south of 'Aimakapa Beach to the southern edge of the rocky shore adjacent to 'Ai'opio Fishtrap (SA: n = 130 counts). Scientific and Hawaiian names are listed in Appendix A.

	NUMBER OF BIRDS		
SPECIES	AIMAKAPA(AP)	KALOKO(KP)	SHORELINE(SA)
Hawaiian Coot	7408*	0	0
Northern Shoveler	2767	0	22
Hawaiian Stilt	2158	148	180
Pied-billed Grebe	306	0	0
Pacific Golden-Plover	213	43	282
Cattle Egret	183	2	0
Wandering Tattler	155	60	149
Unidentified ducks**	228	1	0
Northern Pintail	131	0	0
American Wigeon	85	0	0
Ring-necked Duck	54	0	0
Lesser or Greater Scaup	47	0	0
Lesser Scaup	46	0	0
Mallard***	36	0	0
Black-crowned Night-Heron	33	43	5
Ruddy Turnstone	18	0	790
Canvasback	17	0	0
Long-billed Dowitcher	13	0	0
Sanderling	12	0	98
Greater Scaup	11	0	0
Ring-billed Gull	9	0	2
Redhead	7	0	0
Glaucous-winged Gull	4	0	4
Short-or Long-billed Dowitcher	3	0	0
Sharp-tailed Sandpiper	3	0	0
White-faced Ibis	2	0	0
Other unidentified	2	0	0
Black-bellied Plover	0	0	2
Bristle-thighed Curlew	0	1	0
Unidentified Tern	1	0	0
Lesser Yellowlegs	1	0	0
Unidentified shorebird	1	6	0
Domestic Geese****	0	0	14

*6 of these Hawaiian Coots had red, bulbous shields.
**Of the 228, one group of 84 ducks was described as "mostly Northern Shovelers".
***The same, somewhat blind female Mallard resighted many times on different days; almost certainly of domestic stock origin.
****No longer present after 'Ai'opio's permittees' were relocated.

Table 2. Total numbers of waterbird nests found at 'Aimakapa Fishpond from February through Dec. 1992, Jan. through July 1993, and Jan. through Dec. 1994.

MONTH	HAW. COOT	HAW. STILT	PIED-BILLED GREBE
JANUARY	0	0	0
FEBRUARY	2	1	2
MARCH	3	9	2
APRIL	7	8	2
MAY	10	4	4
JUNE	6	8	4
JULY	11	4	4
AUGUST	4	0	3
SEPTEMBER	2	0	0
OCTOBER	1	0	2
NOVEMBER	0	0	0
DECEMBER	1	0	2
N =	47	34	25

Table 3. Frequency of nests in different areas of 'Aimakapa Fishpond. In each column, the two most frequently used nesting areas are underlined. See Figure 15 for numbered "Pond" areas.

	NUMBER OF NESTS (%)			
	ALL SPECIES COMBINED	COOTS	STILTS	GREBES
NORTHERN SHORELINE	9 (9)	0	<u>9 (27)</u>	0
EASTERN SHORELINE	4 (4)	0	4 (12)	0
SOUTHERN SHORELINE*	13 (12)	7 (15)	6 (18)	0
WESTERN SHORELINE	1 (1)	1 (2)	0	0
"POND" 1	<u>33 (31)</u>	<u>20 (43)</u>	<u>7 (21)</u>	<u>6 (24)</u>
"POND" 2	<u>20 (19)</u>	5 (11)	2 (6)	<u>13 (52)</u>
"POND" 3	18 (17)	<u>11 (23)</u>	4 (12)	3 (12)
"POND" 4	<u>8 (8)</u>	<u>3 (6)</u>	<u>2 (6)</u>	<u>3 (12)</u>
TOTAL	106	47	34	25

*See text for special comments on this area.

Table 4. Frequency of substrates used as nest sites by species* at 'Aimakapa Fishpond. 1992 - 1994 data combined. See text for substrate definitions.

SUBSTRATE	Haw. Coot	Haw. Stilt	Pied-billed Grebe
FLOATING VEG.	12 (26%)	6 (21%)	10 (42%)
ISLET	18 (39%)	2 (7%)	0
FLOATING NEST	3 (6%)	0	14 (58%)
PLATFORM	3 (6%)	8 (29%)	0
ROCKWALL	6 (13%)	5 (18%)	0
SHORELINE	4 (9%)	7 (25%)	0
	46 (100%)	28 (100%)	24 (100%)

*One Coot, one Grebe, and six Stilt nests had unknown substrates.

Table 5.

a. Mean number of eggs per clutch for Hawaiian Stilt nests located at 'Aimakapa Fishpond, Hawai'i Island, in 1993 and 1994.

	1993	1994	Both Years
Mean number of eggs per clutch	3.5	3.2	3.4
S.E.of mean	0.23	0.38	0.20
Number of nests	17	11	28

b. Mean number of fledglings per Hawaiian Stilt nest.*

	1993	1994	Both Years
Mean number of chicks fledged per nest	0.9	1.6	1.1
S.E. of mean	0.25	0.43	0.24
Number of nests	20	14	34

* N of nests in Tables 5a and 5b do not match because some broods were located after hatching, in which case clutch size is not known.

Table 6.
a. Mean number of eggs per clutch for Hawaiian Coot nests located at 'Aimakapa Fishpond, Hawai'i Island, in 1992 through 1994.

	1992	1993	1994	All Years
Mean number of eggs per clutch	5.2	5.0	4.9	5.0
S.E. of mean	0.37	0.49	0.58	0.33
Number of nests	5	25	15	45

b. Mean number of fledglings per Hawaiian Coot nest.*

	1992	1993	1994	All Years
Mean number chicks fledged per nest	0.8	0.8	0.55	0.73
S.E. of mean	0.49	0.32	0.46	0.23
Number of nests	5	21	11	37

* N of nests in Tables 6a. and 6b. do not match primarily because some nests hatched after active field work had ceased and nest outcomes are not known.

Table 7
a. Mean number of eggs per clutch for Pied-billed Grebe nests located at 'Aimakapa Fishpond, Hawai'i Island, in 1992 through 1994.

	1992	1993	1994	All Years
Mean number of eggs per clutch	2.0	3.5	2.1	2.4
S.E. of mean	0.23	0.50	0.40	0.23
Number of nests	11	6	7	24

b. Mean number of fledglings per Pied-billed Grebe nest.

	1992	1993	1994	All Years
Mean number chicks fledged per nest	0.0	0.0	0.0	0.0
S.E. of mean	-	-	-	-
Number of nests	10	6	5	21

Table 8. Frequency of outcomes for breeding waterbird nests with eggs at Aimakapa Fishpond for 1992 through 1994. Outcome code defined in Methods Section. Underlined entries indicate primary nest outcomes for each species.

	Haw. Coot	Haw. Stilt*	Pied-billed Grebe
	Freq.(%)	Freq.(%)	Freq.(%)
OUTCOME			
ABANDONED	3 (6%)	5 (15%)	<u>9 (36%)</u>
DISAPPEARED	4 (6%)	4 (12%)	2 (8%)
FLEDGED	10 (21%)	<u>17 (50%)</u>	0 (0%)
HIGH WATER	<u>17 (36%)</u>	5 (15%)	8 (32%)
NEST SANK	1 (2%)	0 (0%)	0 (0%)
PREDATION	1 (2%)	2 (6%)	0 (0%)
UNCERTAIN	11 (23%)	1 (3%)	6 (24%)
# of nests	47 (100%)	34 (100%)	25 (100%)

* Stilt nests with eggs were not found in 1992; see text.

Table 9. Frequency of outcomes for Hawaiian Coot nests with eggs at Aimakapa Fishpond for 1992 through 1994. Outcome code defined in Methods Section. Underlined entries indicate primary outcomes within each year.

	1992	1993	1994
	Freq.(%)	Freq.(%)	Freq.(%)
OUTCOME			
ABANDONED	1 (20%)	1 (4%)	1 (7%)
DISAPPEARED	1 (20%)	1 (4%)	2 (13%)
FLEDGED	<u>2 (40%)</u>	6 (22%)	2 (13%)
HIGH WATER	1 (20%)	<u>11 (41%)</u>	<u>5 (33%)</u>
NEST SANK	0 (0%)	1 (4%)	0 (0%)
PREDATION	0 (0%)	0 (0%)	1 (7%)
UNCERTAIN	0 (0%)	7 (26%)	4 (27%)
# of nests	5 (100%)	27 (100%)	15 (100%)

Table 10. Frequency of outcomes for Hawaiian Stilt nests with eggs at Aimakapa Fishpond for 1993 and 1994. Outcome code defined in Methods Section. Underlined entries indicate primary outcomes within each year.

OUTCOME	1993 Freq.(%)	1994 Freq.(%)
ABANDONED	3 (15%)	2 (14%)
DISAPPEARED	2 (10%)	2 (14%)
FLEDGED	9 (45%)	8 (57%)
HIGH WATER	4 (20%)	1 (7%)
NEST SANK	0 (0%)	0 (0%)
PREDATION	2 (10%)	0 (0%)
UNCERTAIN	0 (0%)	1 (7%)
# of nests	20 (100%)	14 (100%)

Table 11. Frequency of outcomes for Pied-billed Grebe nests with eggs at Aimakapa Fishpond for 1992 through 1994. Outcome code defined in Methods Section. Underlined entries indicate primary outcomes within each year.

OUTCOME	1992 Freq.(%)	1993 Freq.(%)	1994 Freq.(%)
ABANDONED	2 (18%)	3 (43%)	4 (57%)
DISAPPEARED	0 (0%)	2 (29%)	0 (0%)
FLEDGED	0 (0%)	0 (0%)	0 (0%)
HIGH WATER	6 (55%)	1 (14%)	1 (14%)
NEST SANK	0 (0%)	0 (0%)	0 (0%)
PREDATION	0 (0%)	0 (0%)	0 (0%)
UNCERTAIN	3 (27%)	1(14%)	2 (29%)
# of nests	11 (100%)	7 (100%)	7 (100%)

Table 12. Average Hawaiian Stilt and Hawaiian Coot clutch size and fledglings per nest for different nest substrates. Nests with unknown substrate are omitted. N is the sample size.

	CLUTCH MEAN	(N)	S.D.	FLEDGE MEAN	(N)	S.D
			HAWAIIAN STILT			
ISLET	3.5	2	0.7	2.5	2	0.7
ROCKWALL	4.0	3	0.0	1.6	5	1.6
SHORELINE	3.4	7	1.1	1.0	7	1.4
PLATFORM	3.1	8	1.2	0.8	6	0.4
FLOATING VEG	3.2	6	1.3	0.2	6	0.4
			HAWAIIAN COOT			
PLATFORM	5.0	1	NA	5.0	1	NA
SHORELINE	5.5	4	3.1	2.0	4	1.4
ISLET	4.7	18	2.5	0.8	17	1.4
ROCKWALL	6.2	5	2.3	0.0	5	0.0
FLOATING VEG	5.1	12	1.7	0.0	8	0.0
FLOATING NEST	3.7	3	2.1	0.0	2	0.0

Table 13. Dogs seen per visitor count (DOGS/CT.) and total number of dogs seen during counts (TOT. DOGS) at Aimakapa and Kaloko Fishponds from 1992 through early 1995. See text for discussion of paired counts.

	AIMAKAPA FISHPOND			**KALOKO FISHPOND**		
YEAR	DOGS/CT.	# CTS	TOT. DOGS	DOGS/CT.	# CTS	TOT. DOGS
1992	0.25	67	17	0.0	53	0
1993	0.63	30	19	0.13	23	3
1994	0.11	45	5	0.0	30	0
1995	0.0	4	0	0.0	3	0
TOT. ALL COUNTS*	0.28	146	41	0.03	109	3
TOT. PAIRED COUNTS ONLY	0.29	91	26	0.03	91	3

*From all counts, including paired counts.

Table 14. Average number of visitors per count (AVE./CT.), total number of visitors seen during all counts (TOT. CT.), total number of visitor counts (# CTS.), by type of visitor category, at Aimakapa and Kaloko Fishponds from 1992 through early 1995. Numbers in bold type indicate results from all counts (including paired counts), and numbers in parentheses are from paired counts only. TOTAL PERSONS includes both Park Staff and all visitors.

	AIMAKAPA FISHPOND			KALOKO FISHPONDS		
	AVE./CT.	TOT. CT.	# CTS.	AVE./CT.	TOT. CT.	# CTS.
PARK STAFF	**1.5**(1.4)	**216**(130)	**146**(91)	**3.4**(3.6)	**376**(330)	**109**(91)
VISITORS						
BEACH/ BERM*	**17.6** (17.7)	**2571** (1611)	**146**(91)	**2.7**(3.1)	**293**(279)	**109**(91)
WATER PLAY	**1.6**(1.6)	**227**(146)	**146**(91)	**0.1**(0.1)	**13**(7)	**109**(91)
CONS** USE	**0.3**(0.3)	**40**(24)	**146**(91)	**0.4**(0.3)	**45**(31)	**109**(91)
TOO CLOSE	**0.2**(0.1)	**24**(12)	**146**(91)	**0.03**(0.03)	**3**(3)	**109**(91)
ONLY VISITORS	**19.6**(19.7)	**2862**(1793)	**146**(91)	**3.2**(3.5)	**351**(320)	**109**(91)
TOTAL PERSONS	**21.1**(21.1)	**3078**(1923)	**146**(91)	**6.6**(7.1)	**727**(650)	**109**(91)

* At Kaloko Fishpond, includes people in parking lot.

** Consumptive use of ocean resources, including fishing, limu gathering, etc.

Table 15. Average numbers of visitors and Park staff per count at Kaloko Fishpond for years 1992 through early 1995. Data used is from all counts, including paired counts. *N* is number of counts per year.

YEAR	Ave # Park Staff per Count	Ave # Visitors per Count	*N*
1992	4.1	2.3	53
1993	3.6	3.8	23
1994	2.4	4.1	30
1995	1.7	7.0	3

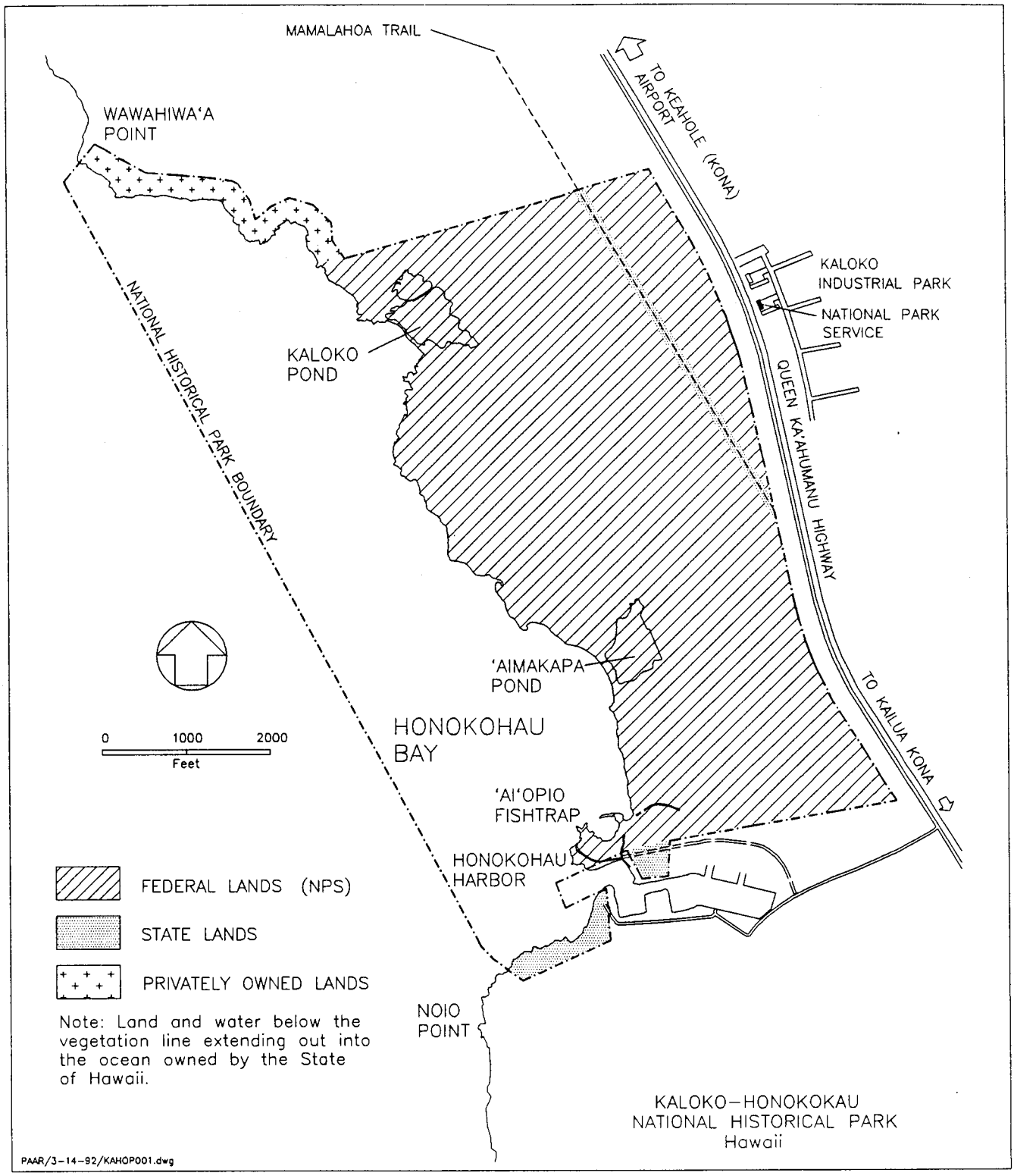


FIGURE 1. Map of Kaloko-Honokōhau National Historical Park, Kona, Hawai'i.

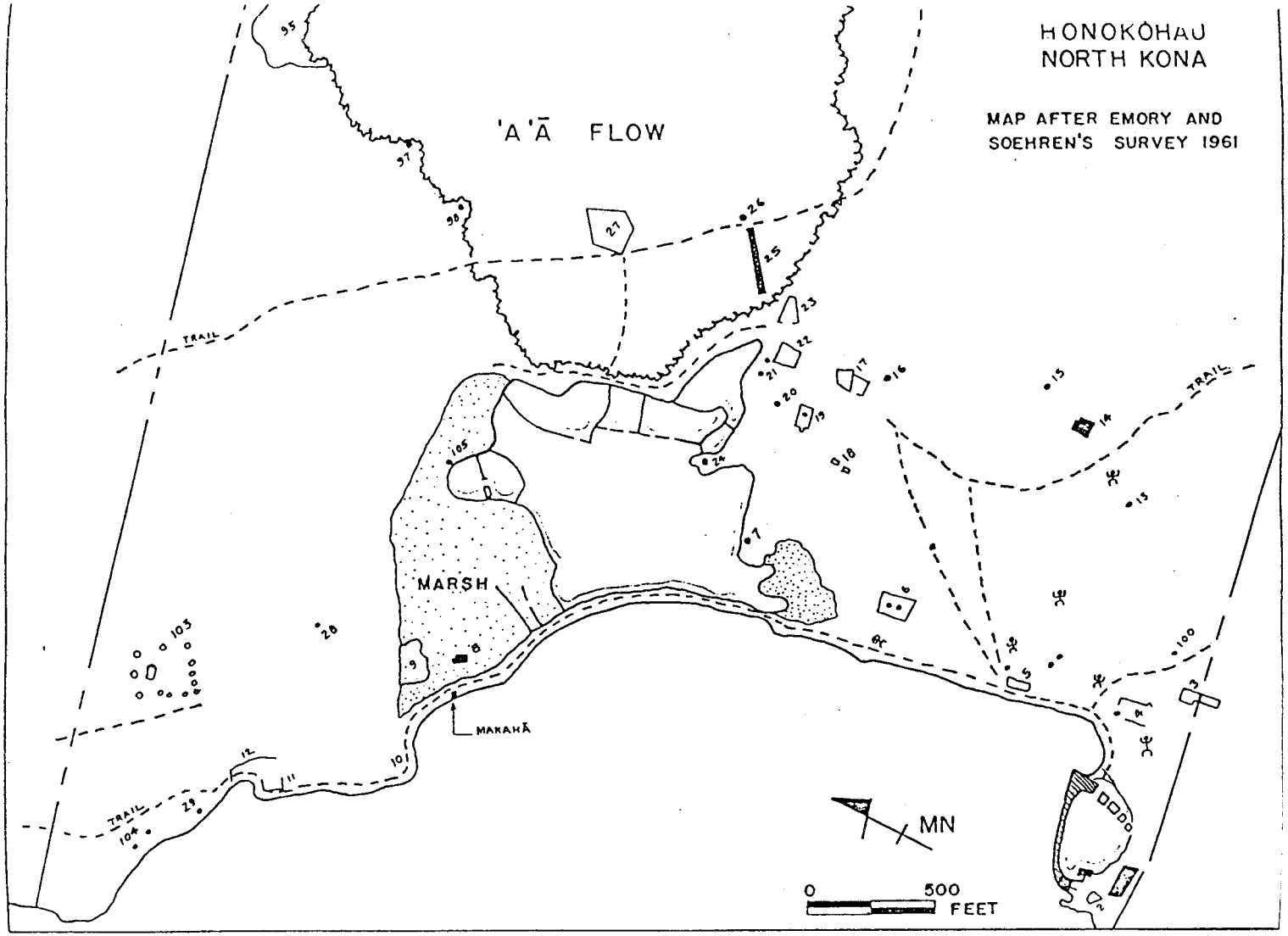


Figure 2. Schematic map of 'Aimakapa Fishpond, from Kikuchi and Belshe (1971), based on Emory and Soehren's 1961 survey, showing approximate location of many fishpond walls and some marshland areas.

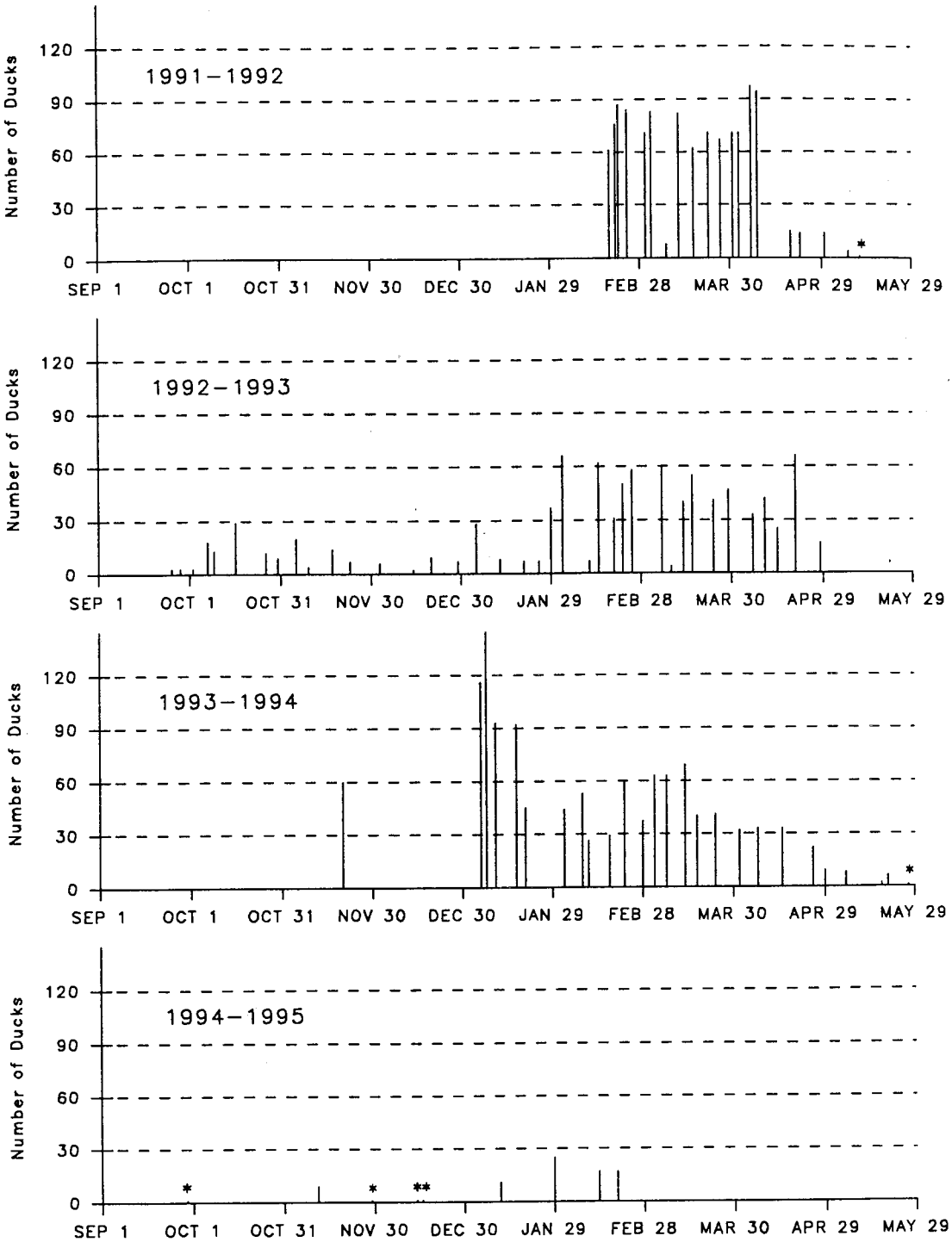


Figure 3. Numbers of ducks counted at 'Aimakapa Fishpond during regular censuses done from Feb. through May 1992, Sept. through May 1992/1993, Jan. through May 1994, and Sept. through Feb. 1994/1995. Censuses were not done during Sept. through Jan. 1991/1992, only one was done during Sept. through Dec. 1993, and no censuses were done in March 1995. An asterisk (*) indicates a count where only one duck was observed.

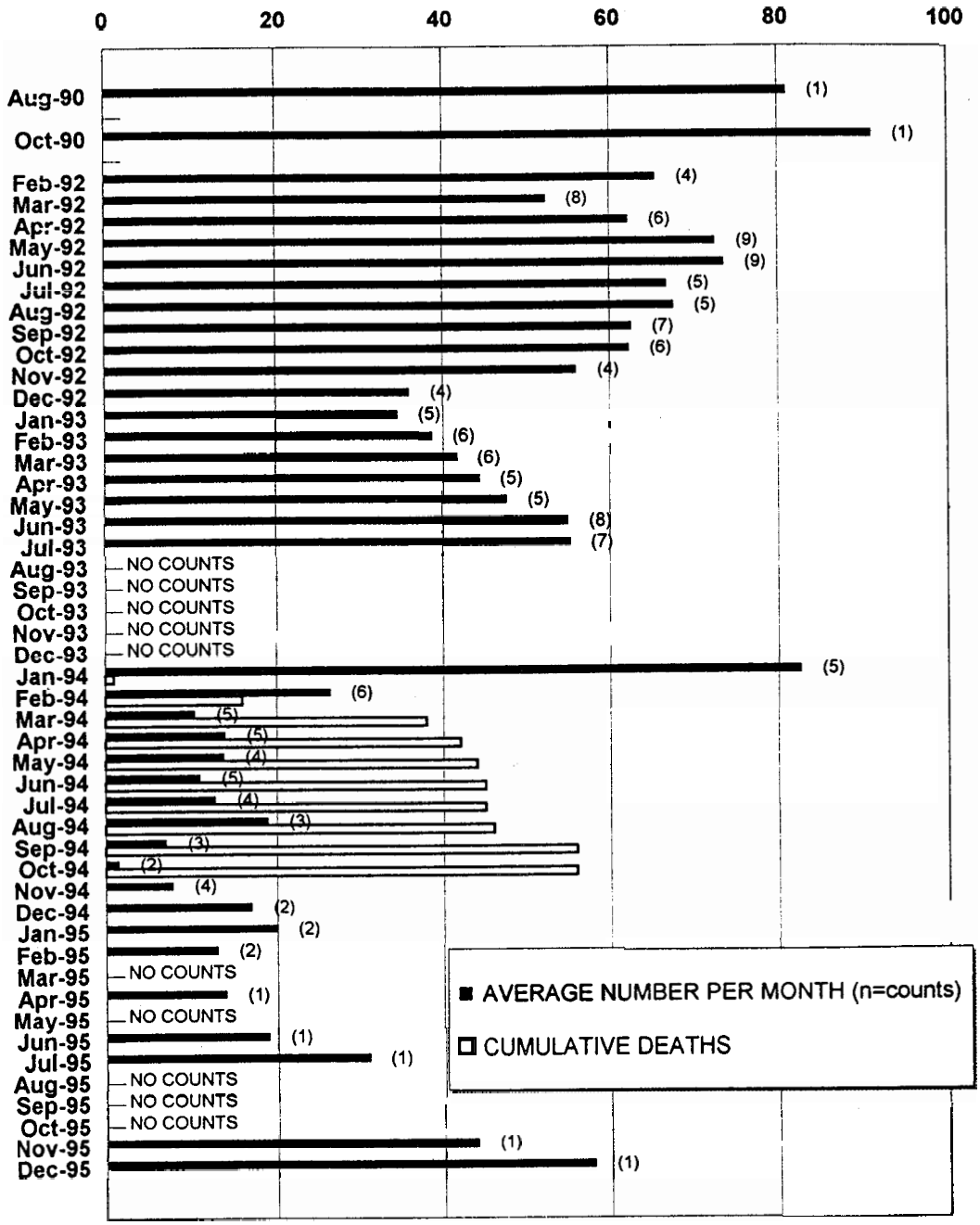


Figure 4. Average Hawaiian Coot population numbers at 'Aimakapa Fishpond from Aug. 1990 through Dec. 1995, and cumulative mortality from botulism during 1994.

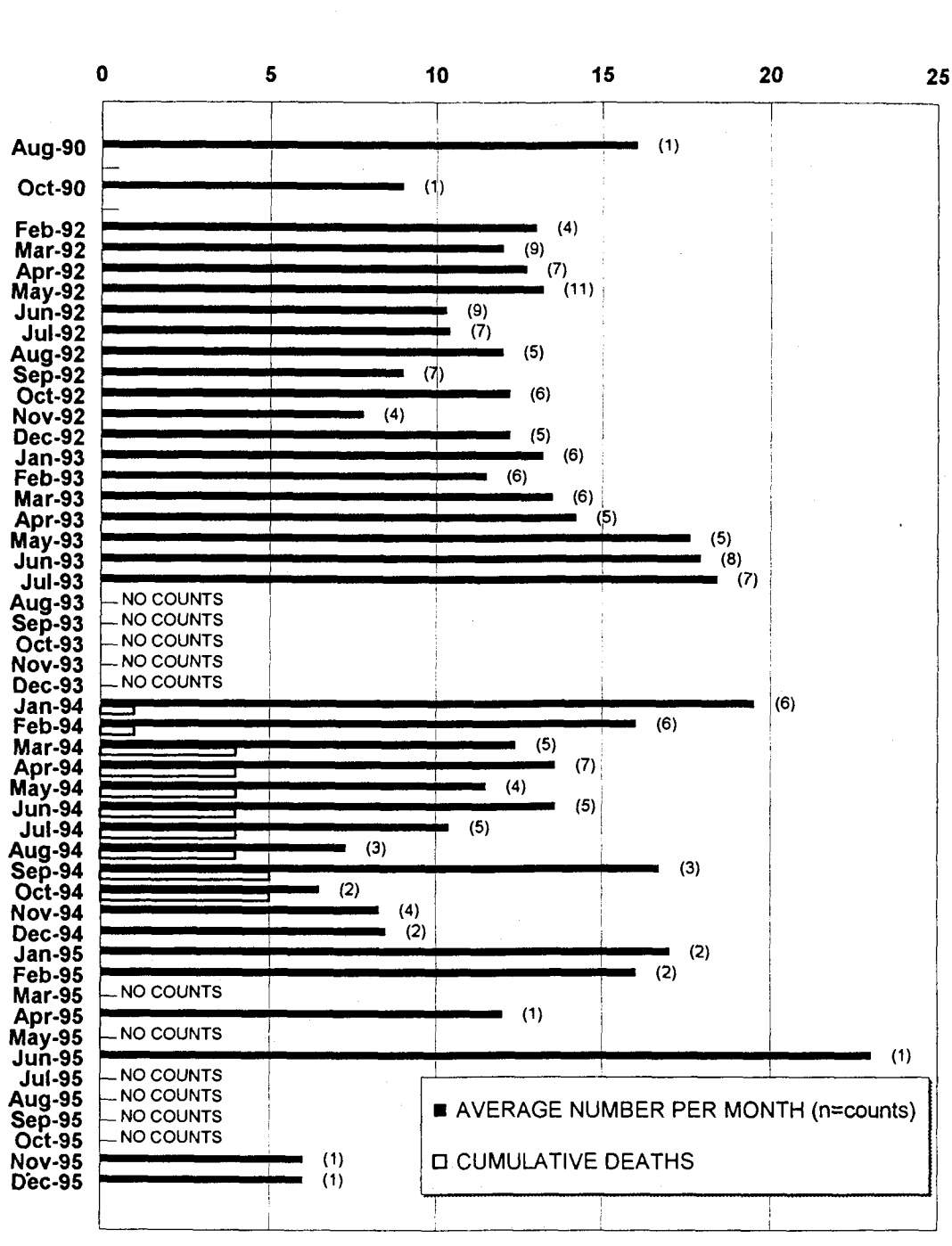


Figure 5. Average Hawaiian Stilt population numbers at 'Aimakapa Fishpond from Aug. 1990 through Dec. 1995, and cumulative mortality from botulism during 1994.

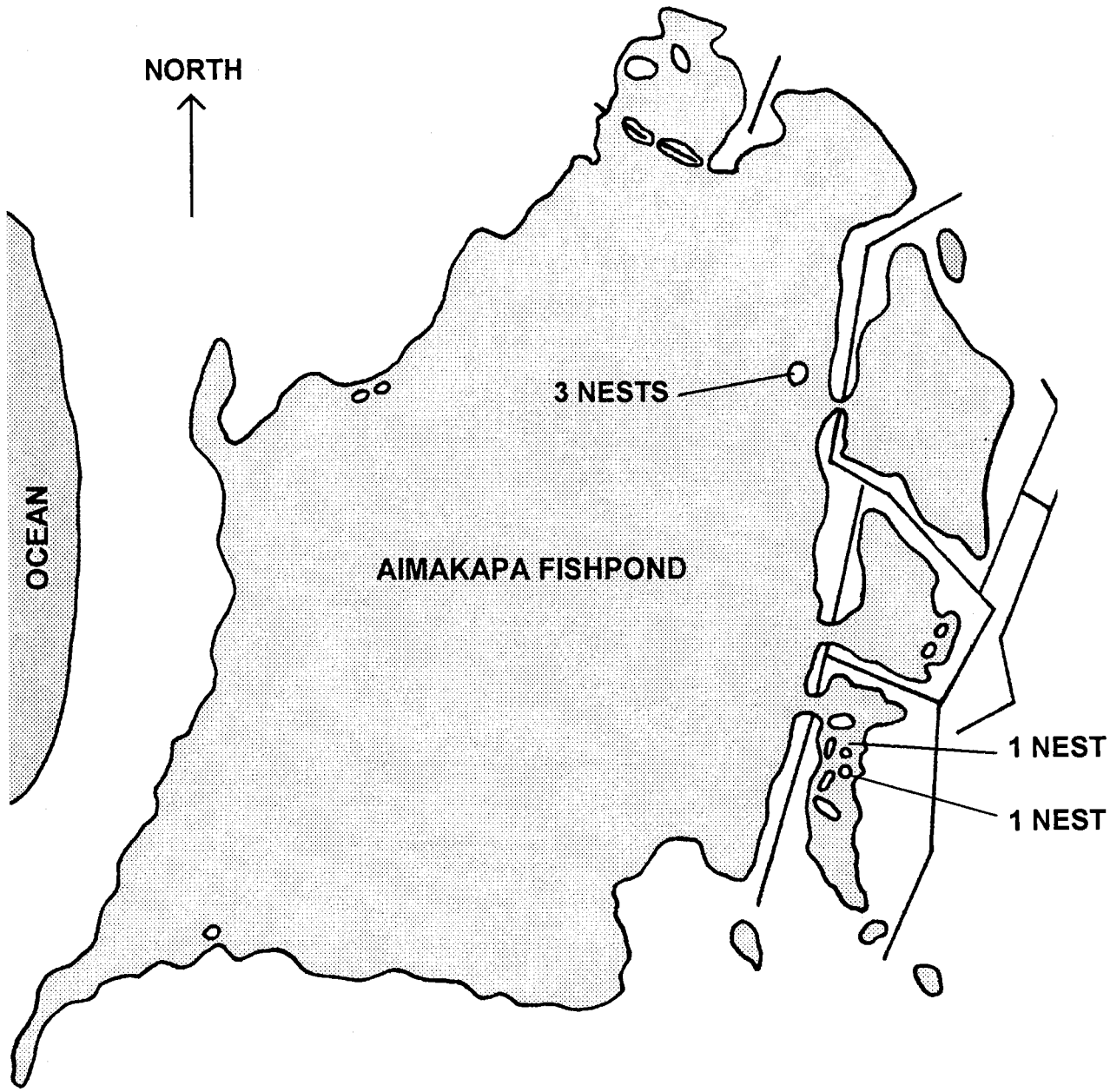


Figure 6. Map of Hawaiian Coot nest locations during 1992 at 'Aimakapa Fishpond, prior to addition of artificial floating platforms. No Stilt nests were found in 1992.

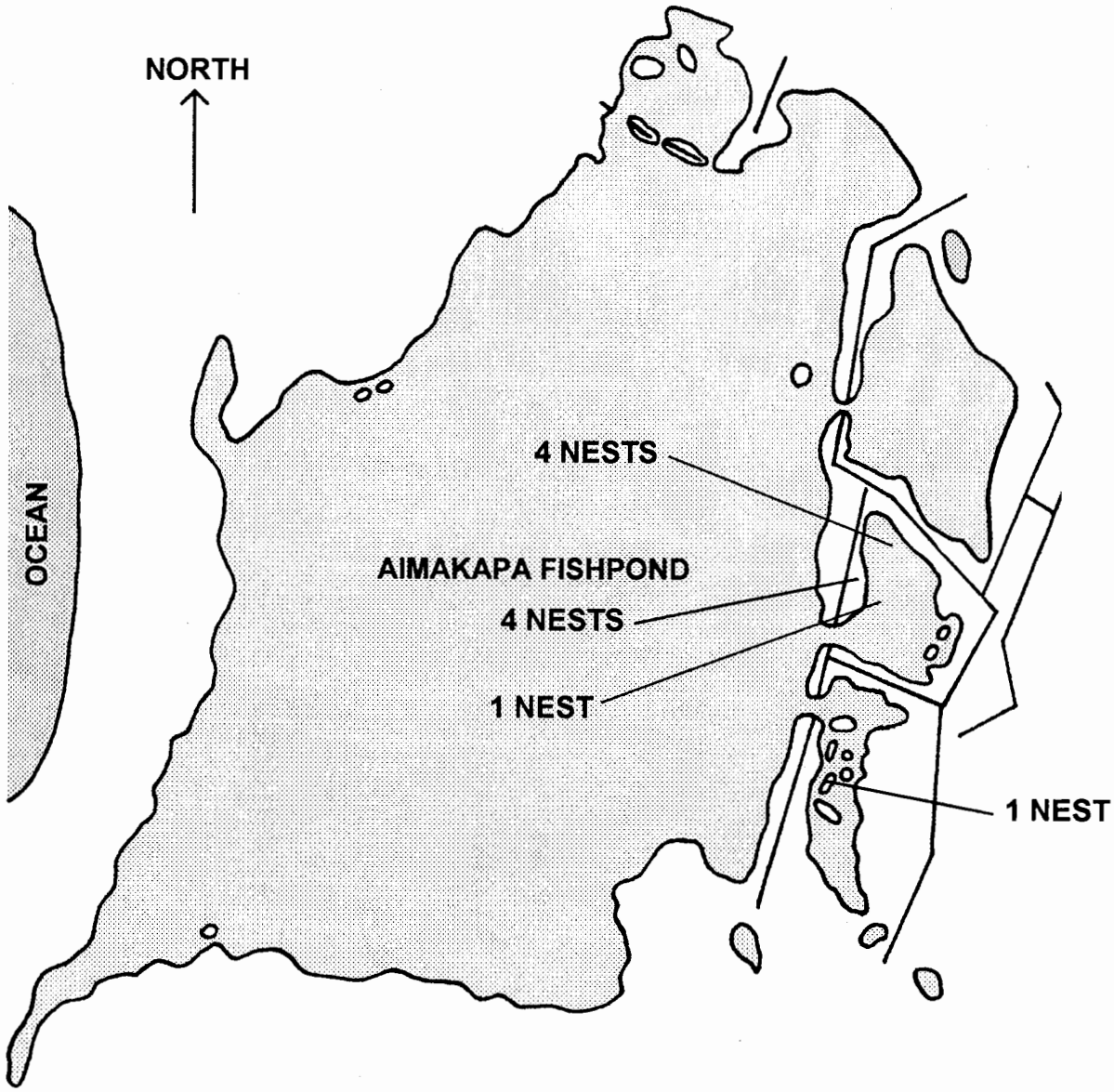


Figure 7. Map of Pied-billed Grebe nest locations during 1992 at 'Aimakapa Fishpond, prior to addition of artificial floating platforms. No Stilt nests were found in 1992.

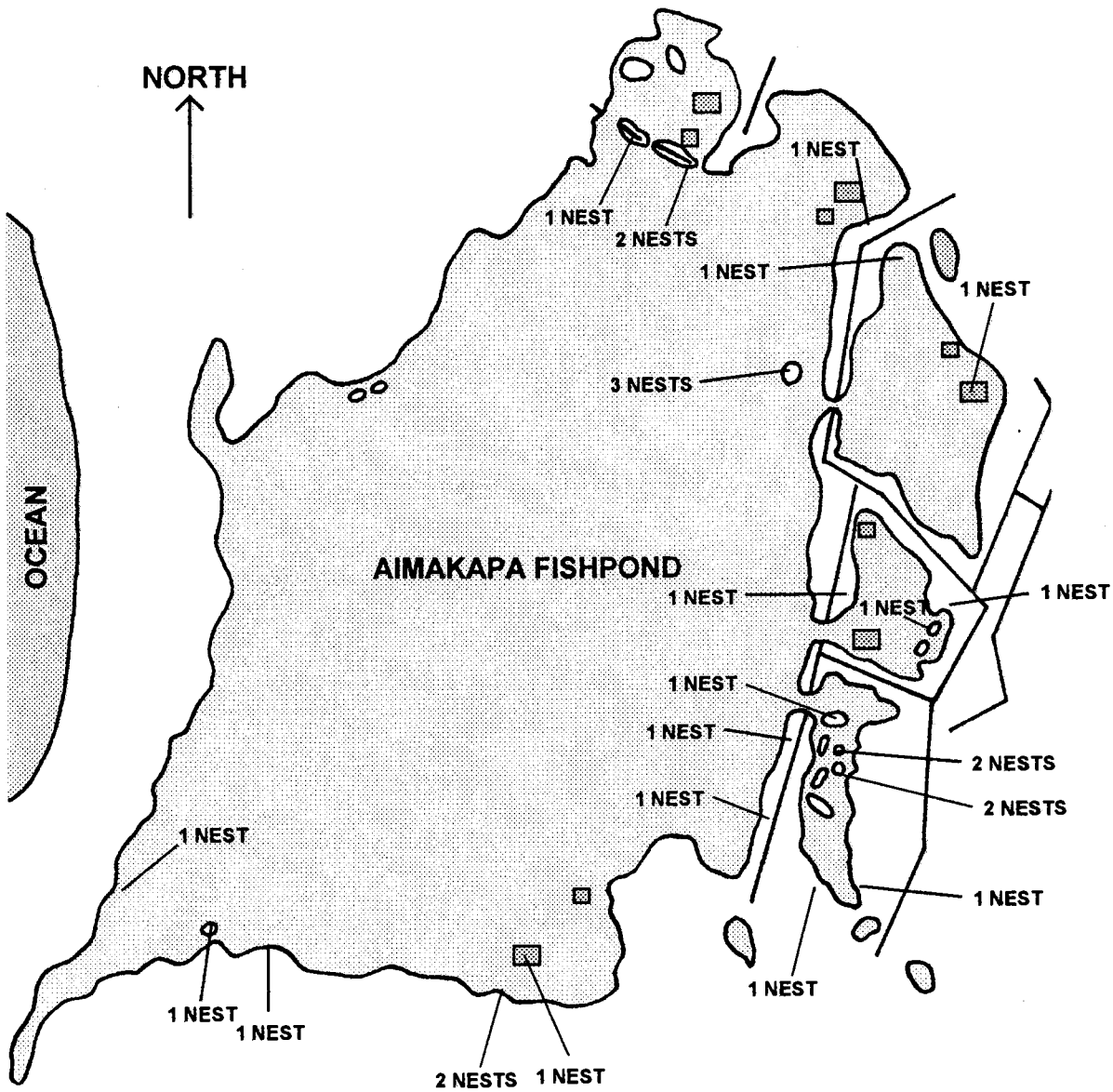


Figure 8. Map of Hawaiian Coot nest locations during 1993 at 'Aimakapa Fishpond. Artificial floating platforms are indicated as squares or rectangles.

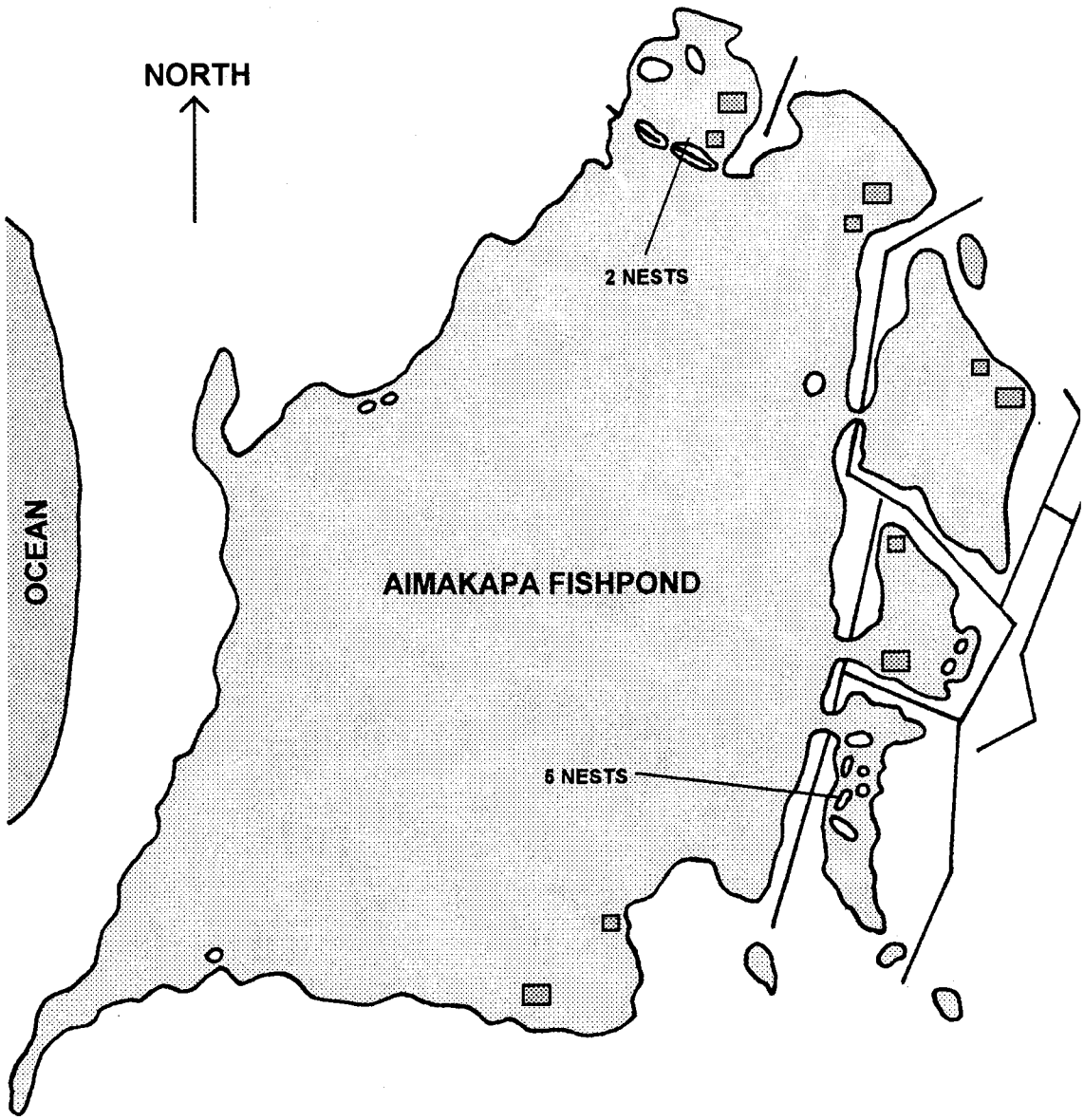


Figure 9. Map of Pied-billed Grebe nest locations during 1993 at 'Aimakapa Fishpond. Artificial floating platforms are indicated as squares or rectangles.

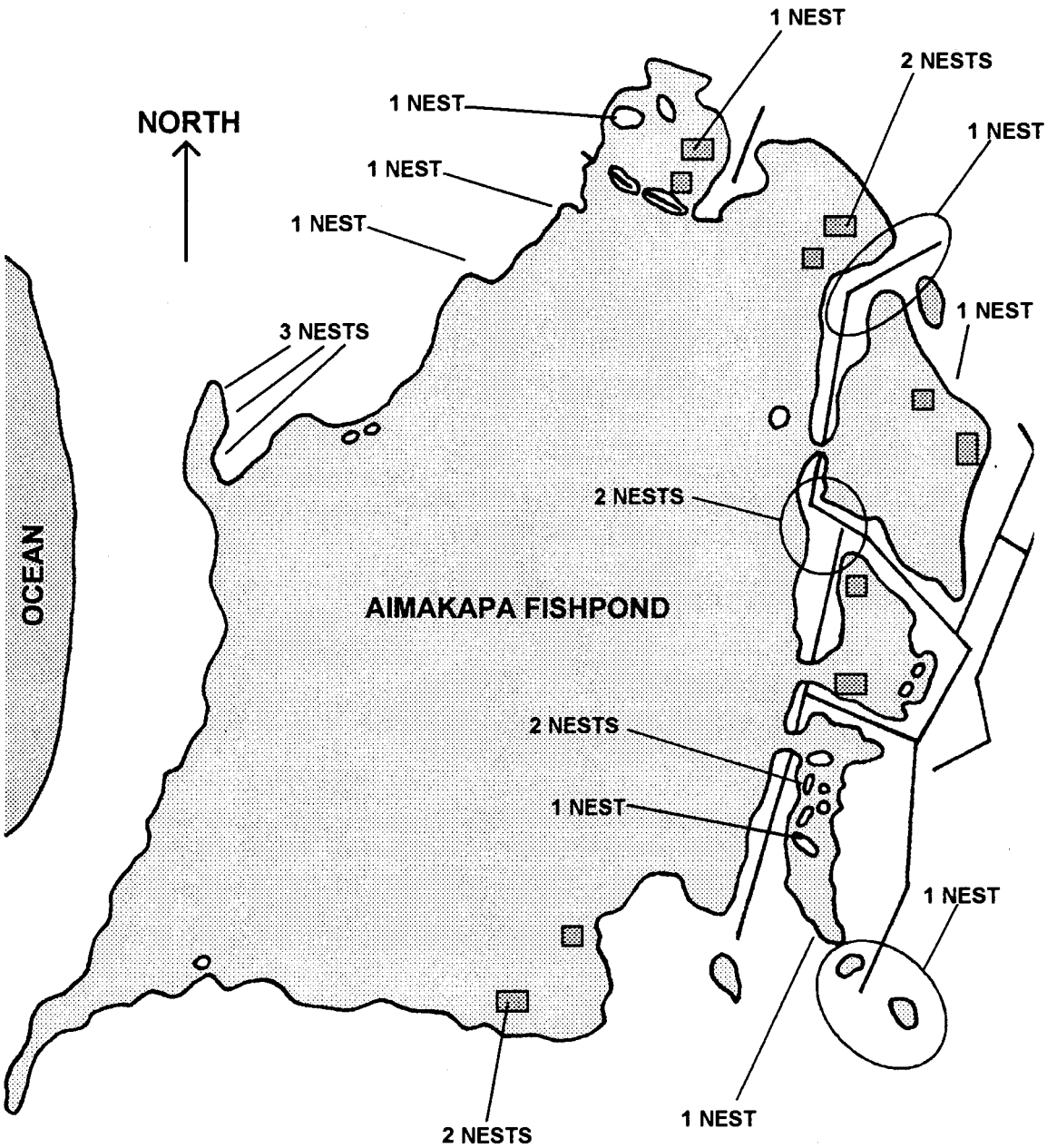


Figure 10. Map of Hawaiian Stilt nest locations during 1993 at 'Aimakapa Fishpond. Artificial floating platforms are indicated as squares or rectangles.

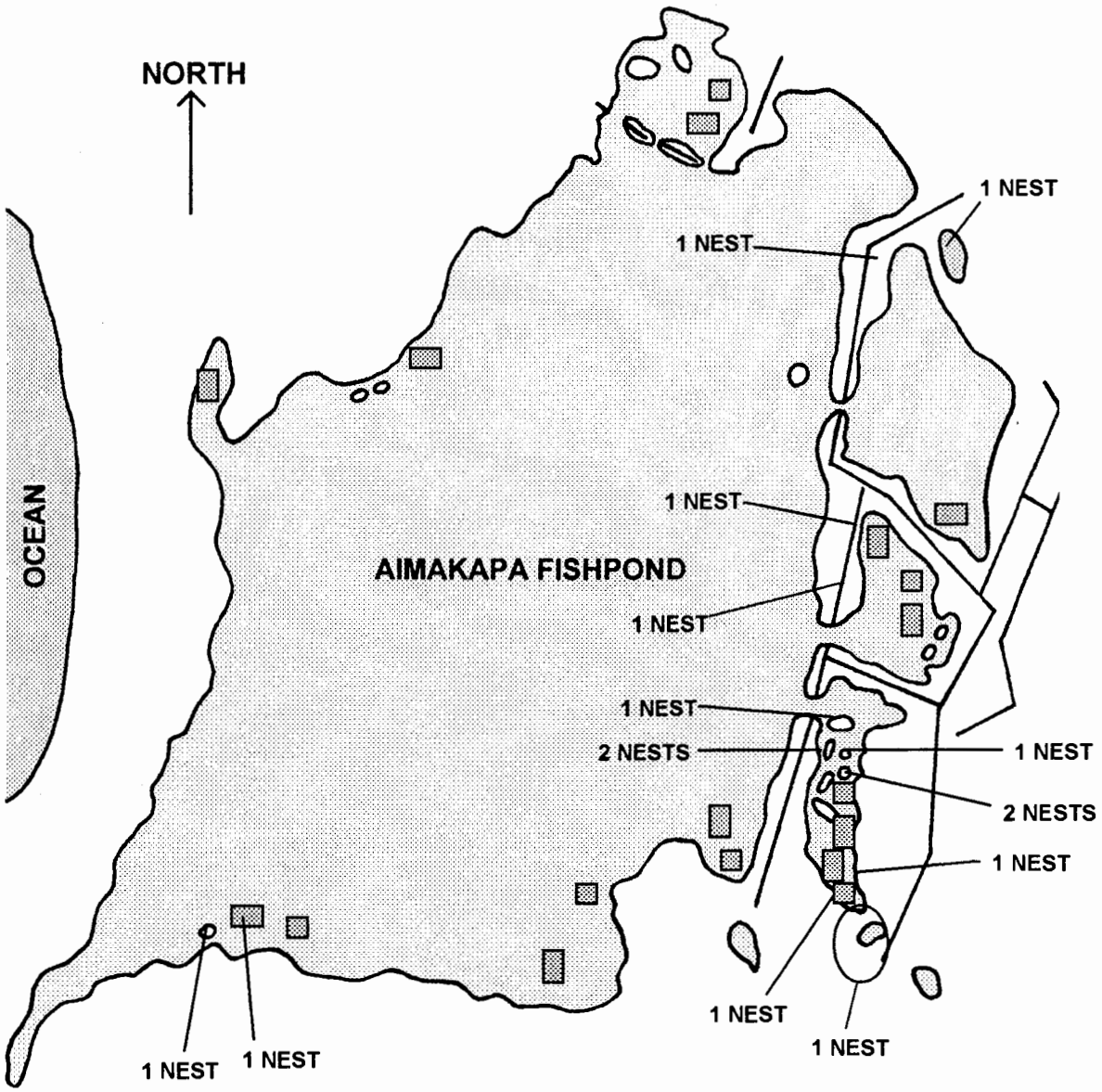


Figure 11. Map of Hawaiian Coot nest locations during 1994 at 'Aimakapa Fishpond. Artificial floating platforms are indicated as squares or rectangles.

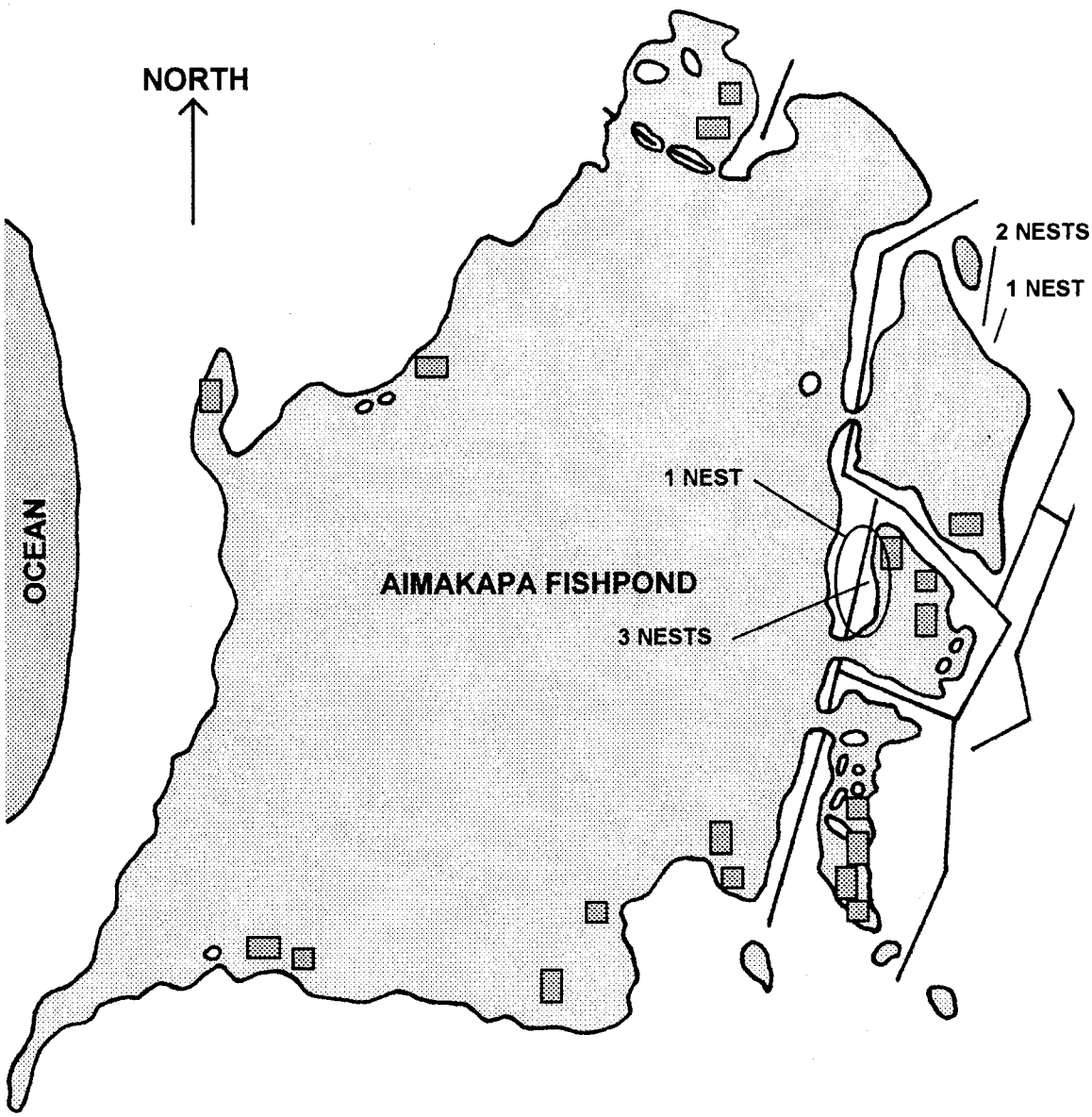


Figure 12. Map of Pied-billed Grebe nest locations during 1994 at 'Aimakapa Fishpond. Artificial floating platforms are indicated as squares or rectangles.

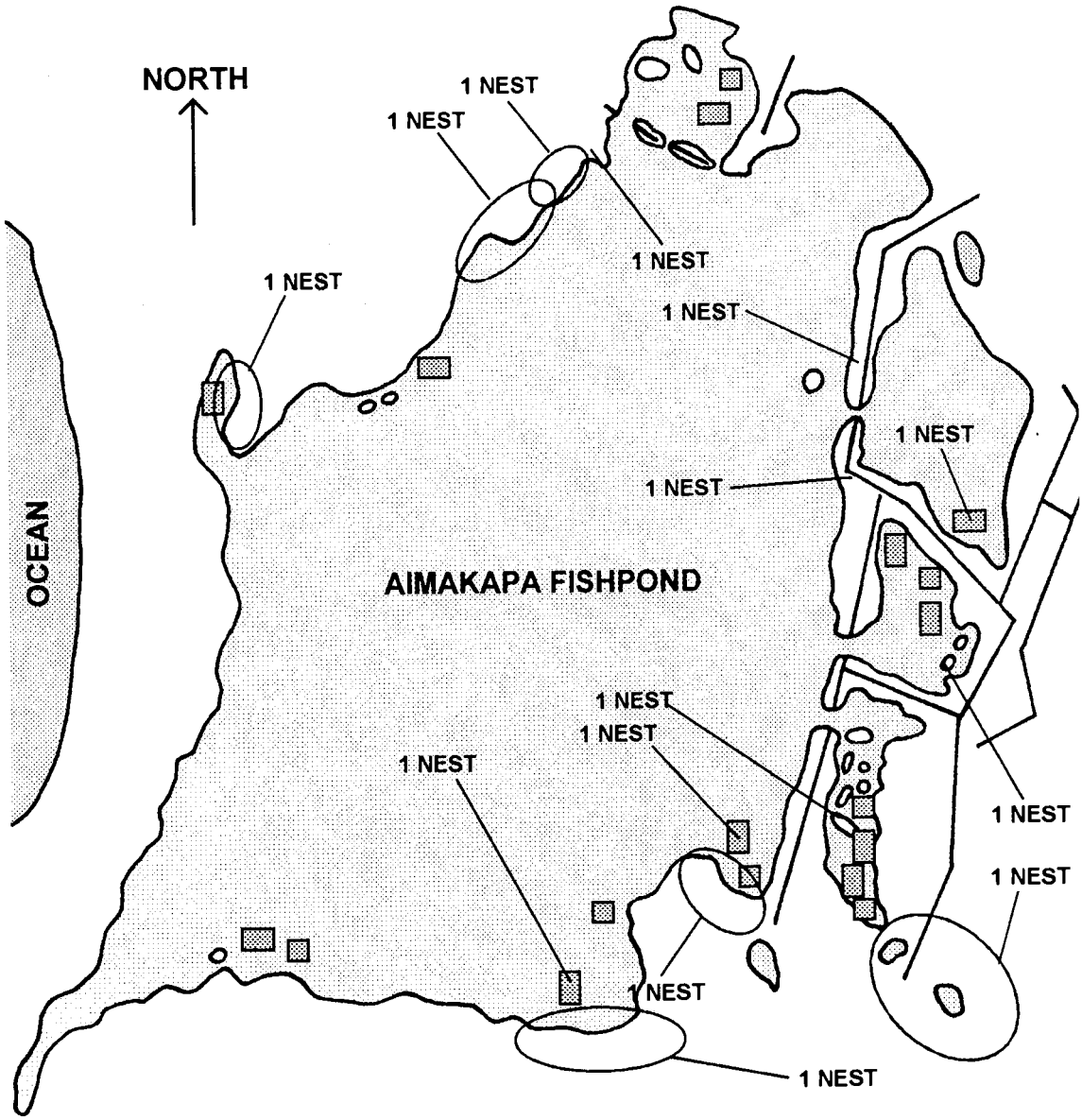


Figure 13. Map of Hawaiian Stilt nest locations during 1994 at 'Aimakapa Fishpond. Artificial floating platforms are indicated as squares or rectangles.

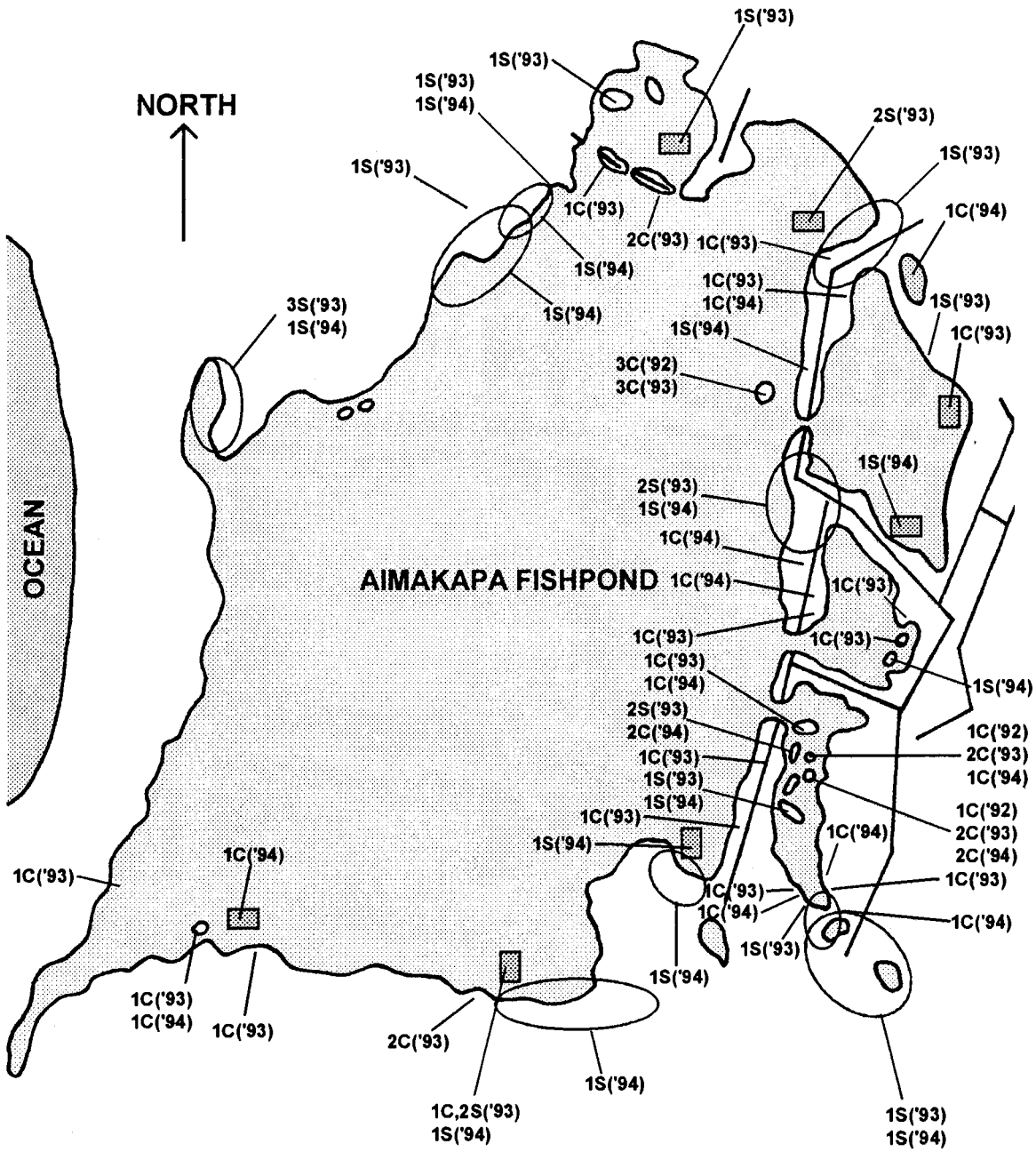


Figure 14. Map of Hawaiian Coot (C) and Hawaiian Stilt (S) nest site locations for 1992-1994 combined. Artificial platforms (represented by squares or rectangles) are shown only if used for nesting. See Figs. 8 - 13 for sites of unused platforms.

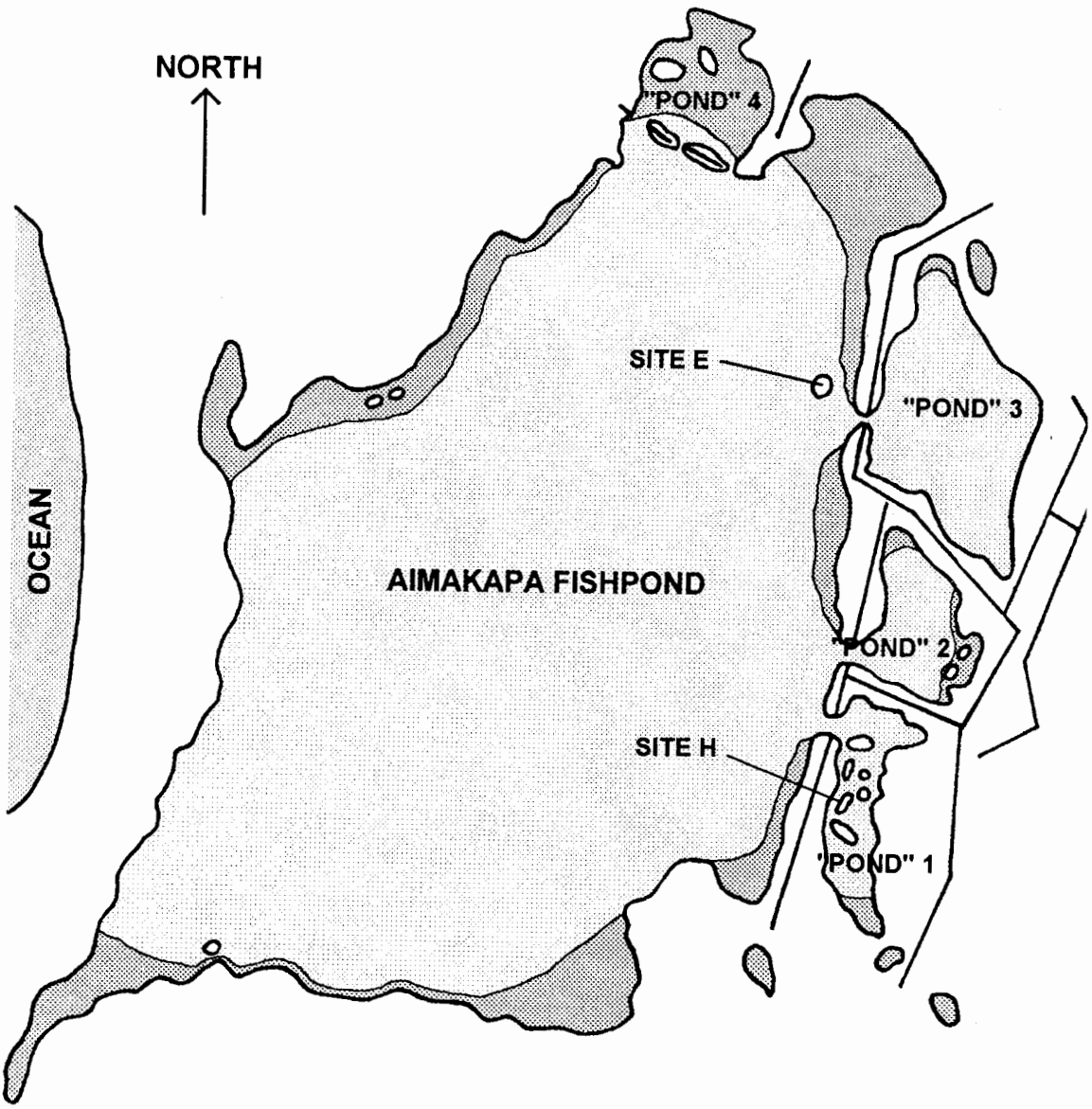
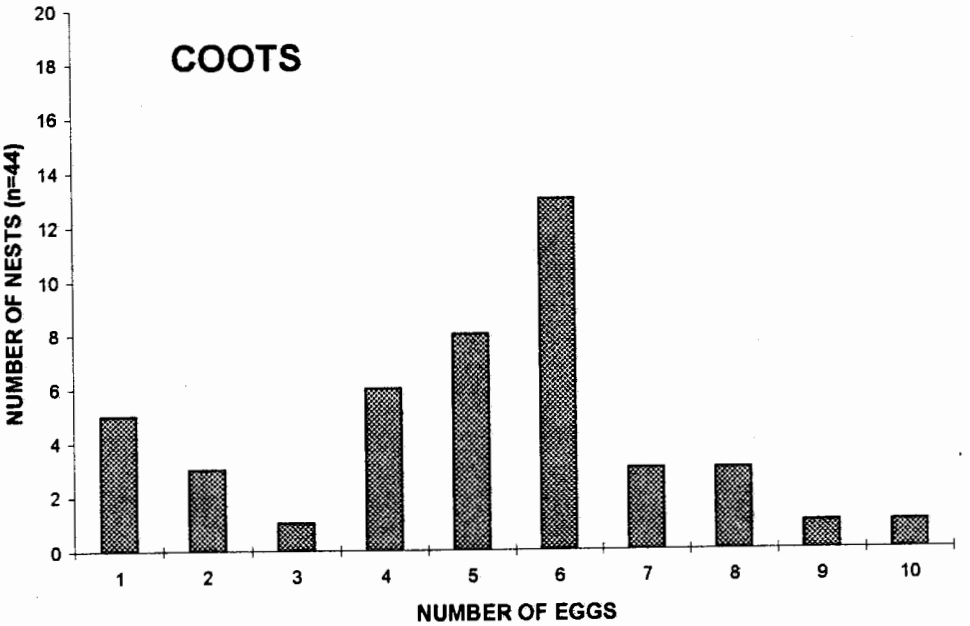


Figure 15. Shaded portions represent mudflats and shallow areas of 'Aimakapa Fishpond during low tides. Numbered "Pond" areas are referenced in Table 3. Sites E and H indicate most frequently used nest sites (see text).



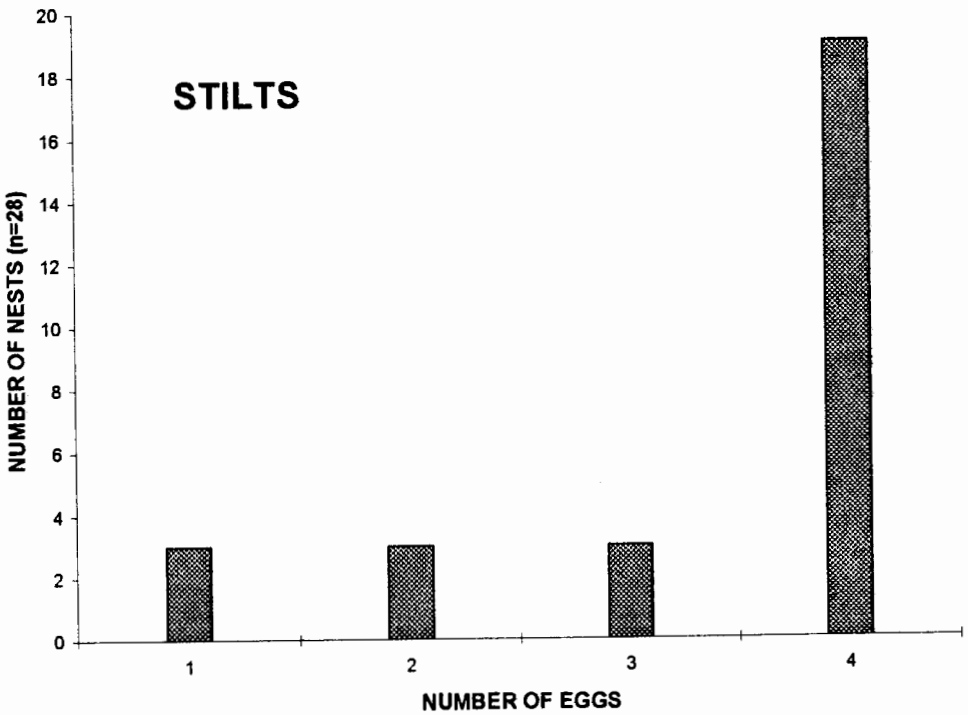
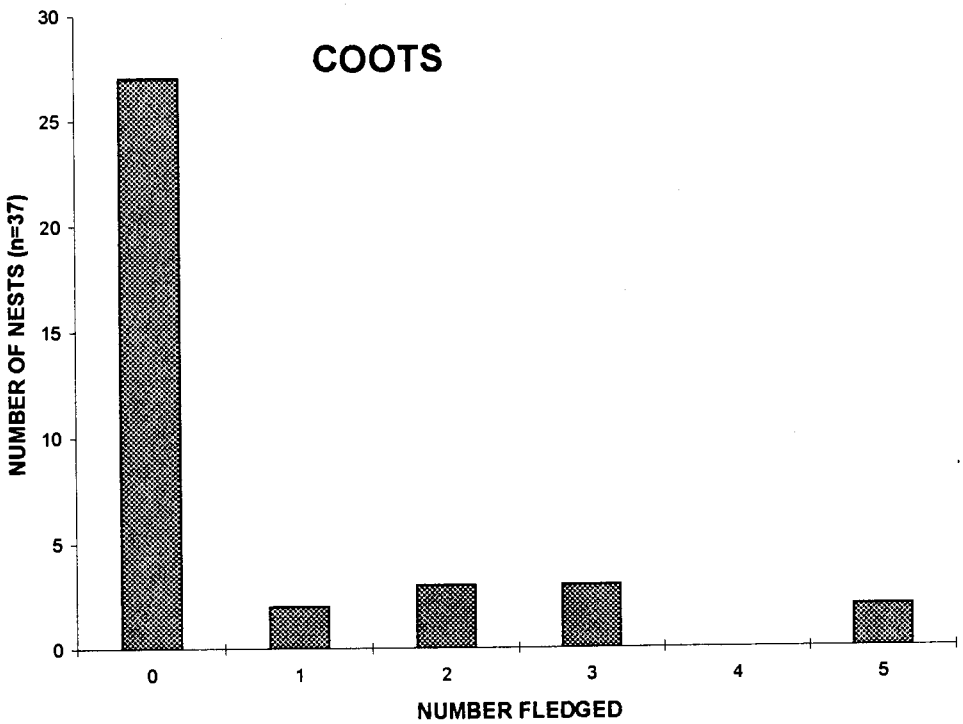


Figure 16. Frequency of endangered waterbird clutch sizes at 'Aimakapa Fishpond, 1992-1994.



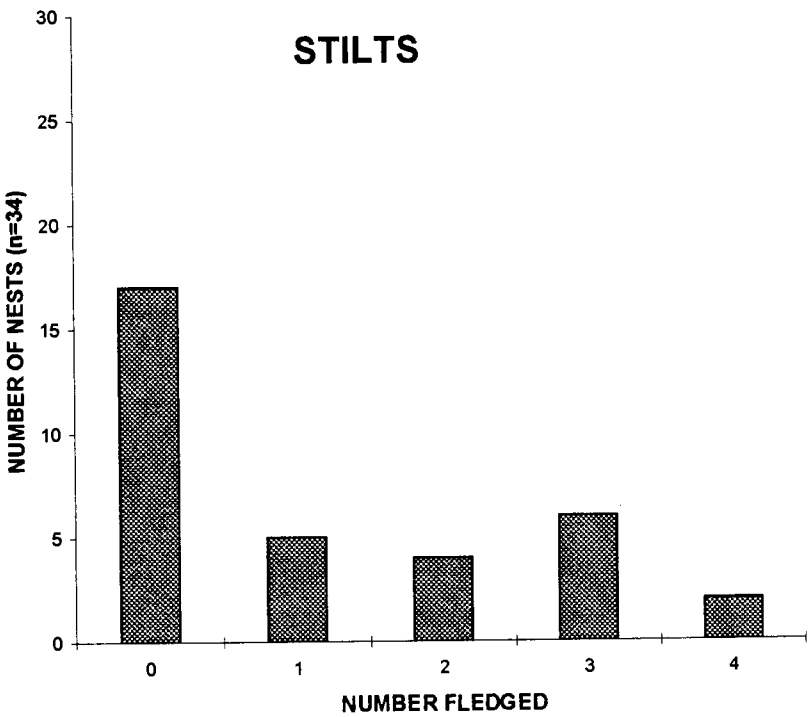


Figure 17. Endangered waterbird fledglings per nest at 'Aimakapa Fishpond, 1992-1994.

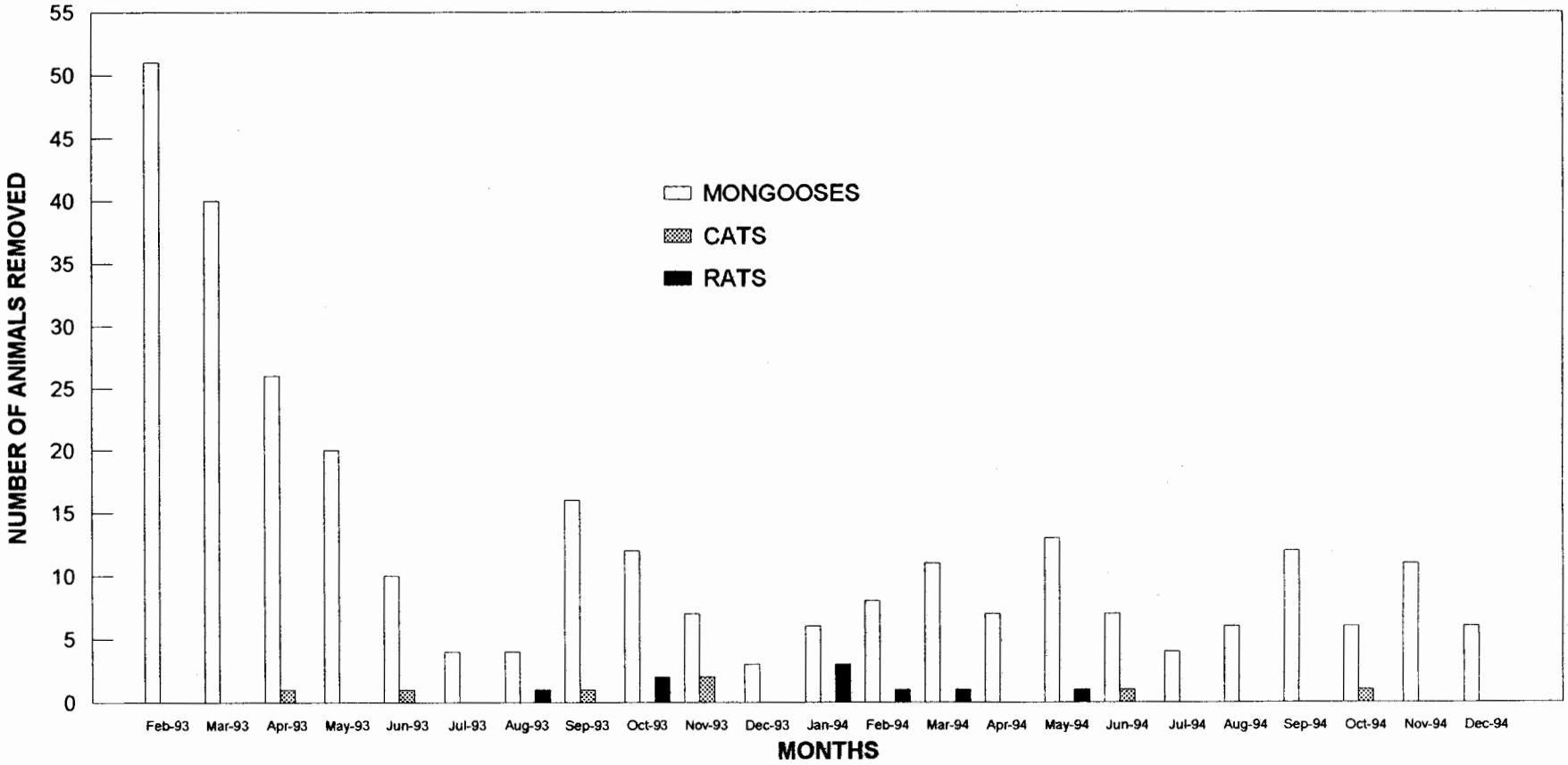


Figure 18. Numbers of predators trapped and removed each month from around 'Aimakapa Fishpond from Feb. 1993 through Dec. 1994.

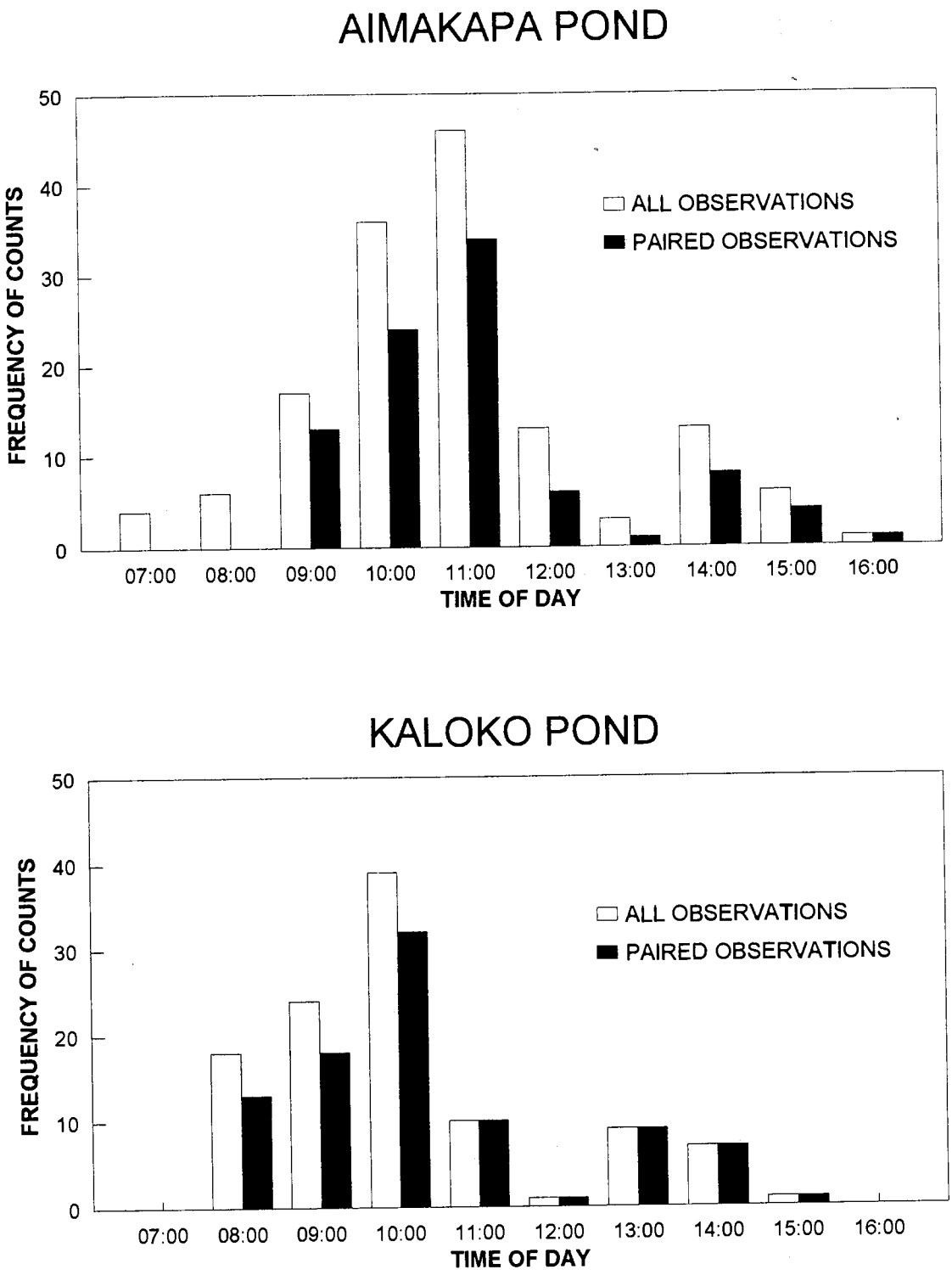


Figure 19. Histogram of time-of-day for visitor counts done prior to bird censuses at 'Aimakapa and Kaloko Fishponds during 1992 through early 1995. Paired observations are defined in Material and Methods section.

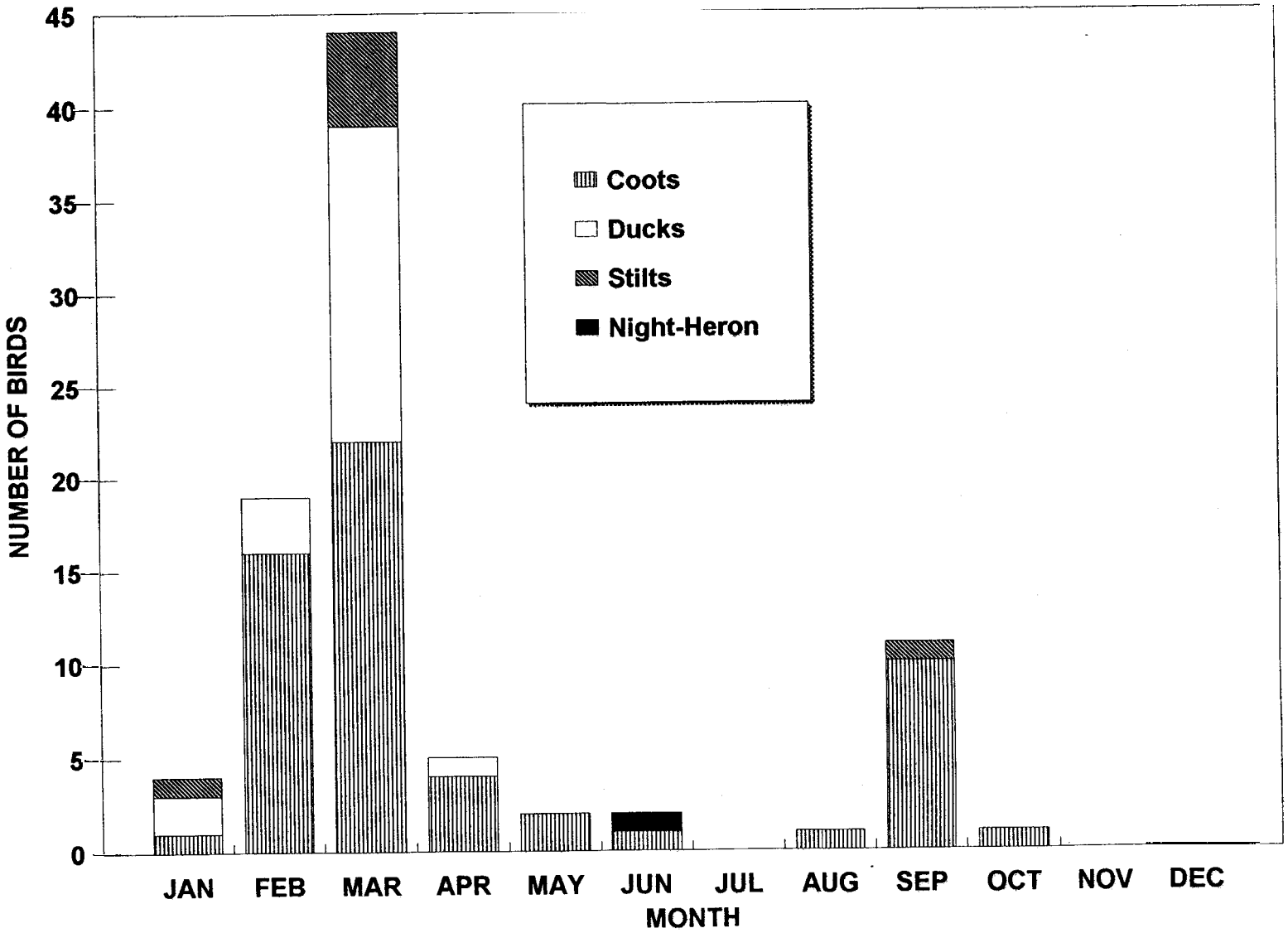


Figure 20. Dead waterbirds found in west Hawai'i Island during 1994 botulism die-off, primarily from 'Aimakapa Fishpond.

Appendix A. List of common, scientific, and Hawaiian bird names, in alphabetical order by common name (see Table 1.).

COMMON NAME	SCIENTIFIC NAME	HAWAIIAN NAME
Canvasback	*Aythya valisineria*	none known
Coot, Hawaiian	*Fulica alai*	'Alae ke'oke'o
Curlew, Bristle-thighed	*Numenius tahitiensis*	Kioea
Dowitcher, Long-billed	*Limnodromus scolopaceus*	none known
Dowitcher, Short-billed	*Limnodromus griseus*	none known
Duck, Ring-necked	*Aythya collaris*	none known
Egret, Cattle	*Bubulcus ibis*	none known
Golden-Plover, Pacific	*Pluvialis fulva*	Kolea
Grebe, Pied-billed	*Podilymbus podiceps*	none known
Gull, Glaucous-winged	*Larus glaucescens*	none known
Gull, Ring-billed	*Larus delawarensis*	none known
Ibis, White-faced	*Plegadis chihi*	none known
Mallard	*Anas platyrhynchos*	none known
Night-Heron, Black-crowned	*Nycticorax nycticorax hoactli*	'Auku'u
Pintail, Northern	*Anas acuta*	Koloa mapu
Plover, Black-bellied	*Pluvialis squatarola*	none known
Redhead	*Aythya americana*	none known
Sanderling	*Calidris alba*	Hunakai
Sandpiper, Sharp-tailed	*Calidris acuminata*	none known
Scaup, Greater	*Aythya marila*	none known
Scaup, Lesser	*Aythya affinis*	none known
Shoveler, Northern	*Anas clypeata*	Koloa moha
Stilt, Hawaiian	*Himantopus mexicanus knudseni*	Ae'o

Tattler, Wandering	*Heteroscelus incanus*	'Ulili
Turnstone, Ruddy	*Arenaria interpres*	'Akekeke
Wigeon, American	*Anas americana*	none known
Yellowlegs, Lesser	*Tringa flavipes*	none known